Dynatech 628
Function Generator

PROPERTY OF
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BLDG. 502 RM. 549

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BLDG. 802 RM. 540

INSTRUCTION MANUAL
MODEL 628
PULSE/FUNCTION GENERATOR

PROPERTY OF
ELEC/MICROWAVE DEPT
BLDG. 802 RM. 540

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CERTIFICATION

This instrument was thoroughly tested and inspected, and found to meet our manufacturing specifications as published, when it was shipped from the factory.

We further certify that our calibration measurements are traceable to the U.S. National Bureau of Standards as applicable.

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SECTION 1

SPECIFICATIONS

1.1 INTRODUCTION

The Model 628 is a combination 20 MHz function generator and pulse generator. It is an extremely versatile instrument because of its many operating modes and its wide range of frequency and other parameters. Some of its major features are:

GPIB Programmable - A comprehensive interface system which includes Service Request and remote triggering (IEEE-488).

Front Panel - All instrument parameters and operating modes are easy to set up by pushbutton.

Auto - Calibration - Self measurement of frequency, symmetry, pulse width, amplitude, offset and lockout level allows the instrument to make corrections to calibrate these parameters itself. A frequency tracking cal mode locks the frequency accuracy to within .1% of setting. Also a complete factory calibration routine is internally stored which steps through all adjustments, manual and automatic, of the instrument.

Error Indications - LED's flash to indicate illegal combinations of programmed settings

1.2 SPECIFICATIONS

WAVEFORM
Sine, Triangle, Haversine, Havertriangle, Square, Pulse (with or without Delay), and Double Pulse.
Invert switch for all waveforms.
DC when untriggered.

FREQUENCY (Note 1)
0.001 Hz to 20 MHz in 8 overlapping ranges.

Resolution:
3 1/2 digits, 1-2000 display counts on each range.
Accuracy with Cal 2 on (frequency tracking):
±0.1% of setting, 1 Hz to 20 MHz.
Accuracy with Cal off:
.2 Hz to 2MHz, ±(1% of range +1% of setting)
2 MHz to 20 MHz, ±(2% of range + 2% of setting)
Stability:
±.05% for 10 minutes
±.25% for 24 hours
VCF Input:
600 ohm input impedance
5V for 2000:1 frequency increase
V:F Output:
1K ohm output impdance
5V out for 2000 counts full scale
Forms ramp waveform in sweep.

1.2 SPECIFICATIONS (CONTINUED)

PULSE WIDTH AND DELAY
- 20 nSec to 2000 Sec
  - Accuracy:
    - ±(5% + 5 nSec)
  - PWM Input:
    - 600 ohm input impedance
    - Pulse width varies inversely with input voltage

AMPLITUDE
- 10 mV to 15 V Pk-Pk, Non-Pulse Waveforms
- 5 mV to 7.5 V O-Pk, Pulse Waveforms
- into 50 ohms, double into high impedance loads.
- Accuracy at 1 KHz
  - ±2% for 15 V to 1.5 V Pk-Pk
  - ±3% for 1.5 V to 150 mV Pk-Pk
  - ±5% for 150 mV to 10 mV Pk-Pk
- Stability:
  - ±.05% for 10 minutes
  - ±.25% for 24 hours
- Flatness, Sinewave:
  - ±.1dB to 100 KHz
  - ±2dB to 20 MHz
- AM Input:
  - 600 ohm input impedance
  - Amplitude varies inversely with input voltage, may be be reduced past 100% (inverted) to full inverted amplitude.

OFFSET
- -7.5 V to +7.5 V into 50 ohms, double into high impedance loads.
- Accuracy at 5 mV Amplitude:
  - ±3% for 7.5 V to 750 mV
  - ±4% for 750 mV to 75 mV
  - ±6% for 75 mV to 7.5 mV

WAVEFORM CHARACTERISTICS (NOTE 1)
- Sine, at 10V Pk-PK:
  - Distortion: ±.5% 10 Hz to 100 KHz
  - Harmonics: -30dB to 12 MHz
    -26dB to 20 MHz
- Triangle Linearity, 10% to 90% of waveform:
  - > 98% for .001 Hz to 100 KHz
  - > 95% to 2 MHz
- Symmetry, time:
  - ±(1% + 10 nSec)
- Square and Pulse at maximum amplitude into 50 ohms:
  - Transition time: <16 nSec
  - Overshoot and ringing:
    - Square: ±5%
    - Pulse: ±10%

1.2 **SPECIFICATIONS** (CONTINUED)

OUTPUTS
- Main:
  - Dual output jacks switchable front to rear.
  - Output impedance: 50 ohms
- Sync:
  - TTL levels: 0 V to 3.5V
  - Output impedance: 50 ohms
  - Transition time: 8 nSec
- TTL Pulse:
  - TTL levels: 0 V to 3.5V
  - Output impedance: 50 ohms
  - Transition time: 8 nSec
- ECL Pulse:
  - ECL levels: -.9 V to -1.7 V
  - Output impedance: 50 ohms
  - Transition time: 3 nSec

OPERATING MODES
- Run: Free running waveform
- Gate: Free runs when trigger on
- Trigger: Single cycle when triggered
- Inhibit: DC only, generator locked out
- Burst: 1 to 2000 counted cycles of the waveform when triggered. May be repeatedly triggered internally by setting Burst Period.
  - Burst Period:
    400 nSec to 2000 Sec for non-pulse waveforms
    1 mSec to 2000 Sec for all waveforms
    - Accuracy:
      ±(5% + 50 nSec), < 2 mSec
      +1%, > 2 mSec
    - Burst Sync: TTL output signal (shared with sweep sync).

TRIGGER SOURCES
- Manual: Front panel pushbutton
- External Trig In:
  - DC coupled
  - Input impedance: >1K ohm
  - Level: 0 V to 15 V adjustable
  - Trigger On LED indicator
- Internally Timed trigger in Burst mode.
- GPIB triggers:
  - Group Execute Trigger (GET) single shot command
  - Steady state GPIB trigger setup commands.

SWEEP
- Linear, any one frequency range may be swept over 3 decades. (1 to 2000 display counts)
- Digitally controlled with selectable step size.
- Start and Stop frequencies may be anywhere within a range.
- Sweep Time:
  - 10 mSec to 2000 Sec
  - Accuracy: ±(.1% + .2 mSec)

1.2 SPECIFICATIONS (CONTINUED)

Sweep Modes: Many and various, sweeps are triggered according to Trigger mode when sweep is on.
Marker Frequency: LED indicators and TTL output signal.
Sweep Sync: TTL output signal (shared with Burst Sync)

GPIB PROGRAMMING
Subsets of IEEE-488:
SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0 ,DC1. DT1. C0, E2
All instrument settings programmable except External Trigger level.

MEMORY
20 complete instrument settings may be stored in non-volatile memory for recall at any time.

DISPLAY
3 1/2 digit yellow LED display
Yellow LED annunciators

POWER REQUIREMENTS
Voltage: 100, 120, 220, or 240 VAC
±10% switch selectable
Frequency: 50-60 Hz
Power Consumption: 120 VA max.
Fuse:
1 1/2 A Slow at 100-120V
3/4 Slow at 220-240 V

ENVIRONMENT
Storage temperature -40° C to +70°C
Operating Temperature: 0°C to +55° C
Specifications Valid: +20°C to +30° C

DIMENSIONS
Height: 3 1/2 inches (8.9 cm)
Width: 17 inches (43.2 cm)
Depth: 13 1/2 inches (34.3 cm)
Weight 17.6 lbs. (8.0 Kg)

MOUNTING OPTIONS AVAILABLE
1: Rack Mount brackets only
2: Rack mount brackets with handles
3: Handles only

NOTES:
1) Frequency and Waveform characteristics specifications are applicable only at frequencies from 10% to 100% of each frequency range.

2) Specifications subject to change without notice.

1.3 VERIFICATION OF SPECIFICATION

1.3.1 EQUIPMENT REQUIRED

To verify the Model 628 specifications you will need the following equipment:

Oscilloscope: DC to 200 MHz, 20 mV/cm with differential comparator
Counter/Timer: .001 Hz to 20 MHz, time interval A to B
Harmonic Distortion Analyzer: <0.1% residual distortion.
Spectrum Analyzer: 100KHz to 100MHz

Before verifying the specifications, turn on the instrument and allow it to warm up for one hour. Refer to Section 2 to verify basic operation of instrument. Perform a user Cal 11 prior to checking specifications.

1.3.2 FREQUENCY ACCURACY

1. Initial Control Settings

TRIGGER	RUN
SWEEP MODE	OFF
AMPLITUDE	10V
OFFSET	OFF
FREQUENCY	20.00 MHz
WAVEFORM	SQU
AUTOCAL	OFF

2. Connect output terminated in 50 ohms to counter/timer.

3. Using Chart 1.3.2, set the 628 frequency as stated and observe the indicated counter reading:

628 SETTING	COUNTER READING Min	Max
20.00 MHz	19.2 MHz	20.8 MHz
02.00 MHz	1.56 MHz	2.44 MHz
2.000 MHz	1.92 MHz	2.08 MHz
0.200 MHz	.156 MHz	.244 MHz
200.0 kHz	196.0 kHz	204.0 kHz
020.0 kHz	17.8 kHz	22.2 kHz
20.00 kHz	19.6 kHz	20.4 kHz
02.00 kHz	1.78 kHz	2.22 kHz
2.000 kHz	1.96 kHz	2.04 kHz
0.200 kHz	4.50 mSec	5.62 mSec
200.0 Hz	4.90 mSec	5.10 mSec
020.0 Hz	45.0 mSec	56.2 mSec
20.00 Hz	49.0 mSec	51.0 mSec
02.00 Hz	450 mSec	562 mSec
2.000 Hz	490 mSec	510 mSec
0.200 Hz	4.50 Sec	5.62 Sec

CHART 1.3.2

1.3 **VERIFICATION OF SPECIFICATIONS** (CONTINUED)

4. Turn on AUTOCAL 2 and repeat the above measurements checking that all frequencies are within .1% of setting. (The last measurement .2 Hz is out of the range of the autocal). It takes several seconds for the frequency to stabilize at each setting.

1.3.3 FREQUENCY STABILIZER

1. Set controls as in Step 1.3.2.1. Set frequency to 2.000 kHz and record the counter reading.

2. Wait 10 minutes and measure the frequency again. It should be within .05% of the previous reading.

3. Wait 24 hours and measure the frequency again. It should be within .25% of the first reading.

1.3.4 TIME SYMMETRY

1. Set controls as in step 1.3.2.1.

2. Set counter to read time interval A to B. Set the counter trigger levels to the center of the waveform. For each frequency in the Chart 1.3.4 make the following calculation:

(Aup - Bdn) - (Adn - Bup)

The result should be less than the number in the chart.

628 FREQUENCY		SYMMETRY ERROR	
20.00	MHz	11	nSec
02.00	MHz	20	nSec
2.000	MHz	20	nSec
0.200	MHz	110	nSec
200.0	kHz	110	nSec
020.0	kHz	1.01	uSec
20.00	kHz	1.01	uSec
02.00	kHz	10	uSec
2.000	kHz	10	uSec
0.200	kHz	100	uSec
200.0	Hz	100	uSec
020.0	Hz	1	mSec
20.00	Hz	1	mSec
02.00	Hz	10	mSec
2.000	Hz	10	mSec
0.200	Hz	100	mSec

CHART 1.3.4

1.3 VERIFICATION OF SPECIFICATIONS (CONTINUED)

1.3.5 PULSE DELAY AND WIDTH

1. INITIAL CONTROL SETTINGS

TRIGGER	RUN
SWEEP MODE	OFF
FREQUENCY	200.0 kHz
WAVEFORM	SINGLE PULSE
PULSE WIDTH	200.0 nSec
PULSE DELAY	0

2. Connect counter/timer to TTL pulse.
   Set counter to measure time interval Aup to Bdn.

3. For each PULSE WIDTH and FREQUENCY setting in Chart 1.3.5, the counter should read between the two indicated numbers. Leave PULSE DELAY AT 0 for all measurements.

628 PULSE WIDTH/DELAY		FREQUENCY		COUNTER READING MIN		MAX	
200.00	nSec	2.00	MHz	185	nSec	215	nSec
020.0	nSec	2.00	MHz	14	nSec	26	nSec
2.000	uSec	200	kHz	1.90	uSec	2.10	uSec
0.200	uSec	200	kHz	185	nSec	215	nSec
20.00	uSec	20.0	kHz	19.0	uSec	21.0	uSec
02.00	uSec	20.0	kHz	1.90	uSec	2.10	uSec
200.0	uSec	2.00	kHz	190	uSec	210	uSec
020.0	uSec	2.00	kHz	19.0	uSec	21.0	uSec
2.000	mSec	200	Hz	1.90	mSec	2.10	mSec
0.200	mSec	200	Hz	.19	mSec	.21	mSec
20.00	mSec	20	Hz	19.0	mSec	21.0	mSec
02.00	mSec	20	Hz	1.90	mSec	2.10	mSec
200.0	mSec	2.000	Hz	190	mSec	210	mSec
020.0	mSec	2.000	Hz	19.0	mSec	21.0	mSec
0.200	Sec	0.200	Hz	.190	Sec	.210	Sec
02.00	Sec	.20	Hz	1.90	Sec	2.10	Sec
020.0	Sec	.02	Hz	19.0	Sec	21.0	Sec
0200	Sec	.002	Hz	190	Sec	210	Sec

CHART 1.3.5

4. Set PULSE WIDTH to 20 Sec and move the counter to SYNC OUT.

5. For each PULSE DELAY and FREQUENCY setting in chart 1.3.4, the counter should read between the two numbers shown. Leave PULSE WIDTH at 20 nSec for all measurements.

1.3 VERIFICATION OF SPECIFICATIONS (CONTINUED)

1.3.6 SWEEP TIME

1. INITIAL CONTROL SETTING

TRIGGER	RUN
SWEEP	CONTINUOUS
START FREQ	100 kHz
STOP FREQ	10 Khz
WAVEFORM	SINE
SWEEP TIME	200 mSec

2. Connect counter/timer to SWP/BURST SYNC OUT. Set it to measure time interval Aup to Bdn.

3. Using Chart 1.3.6, for each sweep time setting measure a time between the two limits.

628 SWEEP TIME	COUNTER READING MIN	MAX
200.0 mSec	199.6 mSec	200.4 mSec
010.0 mSec	9.79 mSec	10.21 mSec
0.100 Sec	99.7 mSec	100.3 mSec
01.00 Sec	.9988 Sec	1.0012 Sec
010.0 Sec	9.99 Sec	10.01 Sec
0100 Sec	99.9 Sec	100.1 Sec

CHART 1.3.6

1.3.7 BURST PERIOD

1. INITIAL CONTROL SETTINGS

TRIGGER	BURST
SWEEP	OFF
FREQ	20 MHz
BURST COUNT	1
BURST PERIOD	400 nSec
WAVEFORM	SINE

2. Connect counter/timer to SWP/BURST SYNC OUT terminated into 50 ohms. Set it to measure period.

3. Use Chart 1.3.7 to check accuracy of burst period

628 BURST PERIOD		COUNTER READING MIN		MAX	
0.400	uSec	330	nSec	470	mSec
2.000	uSec	1.85	uSec	2.15	uSec
01.00	uSec	.90	uSec	1.10	uSec
20.00	uSec	18.95	uSec	21.05	uSec
010.0	uSec	9.45	uSec	10.55	uSec
200.0	uSec	190	uSec	210	uSec
0.100	mSec	95	uSec	105	uSec
2.000	mSec	1.9	mSec	2.10	mSec
01.00	mSec	.99	mSec	1.01	mSec
20.00	mSec	19.8	mSec	20.1	mSec
010.0	mSec	9.9	mSec	10.1	mSec
0.100	Sec	99	mSec	101	mSec
01.00	Sec	.99	Sec	1.01	Sec
010.0	Sec	9.9	Sec	10.1	Sec
0100	Sec	99	Sec	101	Sec

CHART 1.3.7

1.3.8 BURST COUNT

1. INITIAL CONTROL SETTINGS

TRIGGER	BURST
SWEEP	OFF
AMPLITUDE	10 V
OFFSET	OFF
FREQUENCY	2 MHz
BURST PERIOD	0
BURST COUNT	1
WAVEFORM	SQUARE

2. Connect MAIN OUTPUT to counter timer. Set counter to totalize mode.

3. Each time MANUAL TRIGGER is depressed, the counter will count the number of cycles in the burst. Verify that the count is correct for the following BURST COUNT NUMBERS; 1, 2, 4, 8, 10, 20, 40, 80, 100, 200, 400, 800, 1000, 2000.

1.3.9 AMPLITUDE

1. INITIAL CONTROL SETTINGS

TRIGGER	RUN
SWEEP	OFF
AMPLITUDE	15V
OFFSET	OFF
FREQUENCY	2 kHz
WAVEFORM	SINE
INVERT	OFF

1.3 VERIFICATION OF SPECIFICATIONS

2. Connect MAIN OUTPUT terminated into 50 ohms to scope with differential comparator.

3. Use Chart 1.3.9.3 to verify accuracy of peak to peak amplitude for SINE, TRIANGLE, SQUARE and INVERTED waveforms.

4. Use Chart 1.3.9.4 to verify accuracy of PULSE amplitude.

5. Measure the amplitude of any waveform at any amplitude and record it. Wait 10 minutes and measure it again. The second measurement should be within ±.05% of the first. Wait 24 hours and measure it again. This should be within .25% of the first measurement.

628 AMPLITUDE (any waveform except pulse)	**MEASURED VALUE MIN**	**MAX**
15.00 V	14.7 V	15.3 V
01.51 V	1.48 V	1.54 V
1.500 V	1.455 V	1.545 mV
0.151 V	146.5 mV	155.5 mV
150.0 mV	142.5 mV	157.5 mV
015.0 mV	14.25 mV	15.75 mV

CHART 1.3.9.3

628 AMPLITUDE (PULSE)	**MEASURED VALUE MIN**	**MAX**
07.50 V	7.35 V	7.65 V
01.50 V	1.47 V	1.53 V
0.750 mV	727.5 mV	772.5 mV
0.150 mV	145.5 mV	154.5 mV
075.0 mV	71.25 mV	78.75 mV
015.0 mV	14.25 mV	15.75 mV

CHART 1.3.9.4

1.3.10 OFFSET

1. INITIAL CONTROL SETTINGS

TRIGGER	INHIBIT
SWEEP	OFF
AMPLITUDE	10 mV
WAVEFORM	TRIANGLE (non haver)
OFFSET	0 V, ON

2. Use Chart 1.3.10 to verify offset accuracy.

1.3 **VERIFICATION OF SPECIFICATIONS** (CONTINUED)

628 OFFSET		MEASURED VALUE MIN		MAX	
+ 07.50	V	+ 7.275	V	+ 7.725	V
+ 00.76	V	+ .7372	V	+ .7828	V
- 00.76	V	- .7372	V	- .7828	V
- 07.50	V	- 7.275	V	- 7.725	V
+ 0.750	V	+ 720	mV	+ 780	mV
+ 0.076	V	+ 73	mV	+ 79	mV
- 0.076	V	- 73	mV	- 79	mV
- 0.750	V	- 720	mV	- 780	mV
+ 075.0	mV	+ 70.5	mV	+ 79.5	mV
+ 007.5	mV	+ 7.05	mV	+ 7.95	mV
- 007.5	mV	- 7.05	mV	- 7.95	mV
- 075.0	mV	- 70.5	mV	- 79.5	mV

CHART 1.3.10

1.3.11 SINE DISTORTION

1. INITIAL CONTROL SETTINGS

TRIGGER	RUN
SWEEP	OFF
AMPLITUDE	10V
OFFSET	OFF
FREQUENCY	2 kHz
WAVEFORM	SINE

2. Connect MAIN OUTPUT to distortion analyzer. Measure distortion of less than .5%

3. Connect MAIN OUTPUT terminated into 50 ohms to spectrum analyzer. Set frequencies to 12 MHz. Observe no harmonics above -30dB.

4. Set frequency to 20 MHz and observe no harmonics above -26dB.

1.3.12 TRIANGLE LINEARITY

1. INITIAL CONTROL SETTINGS
   Same as Step 1.3.11.1 except select Triangle.

2. Connect the MAIN OUTPUT to the oscilloscope.

3. Adjust oscilloscope to obtain one-half of triangle across full horizontal grid on oscilloscope CRT.

1.3 **VERIFICATION OF SPECIFICATIONS** (CONTINUED)

4. Set oscilloscope sensitivity at 20 mV/cm.

5. Adjust comparison voltage until the slope of the triangle waveform intersects the mid-scale horizontal grid line at the second major mark as shown in figure 1.3.12.

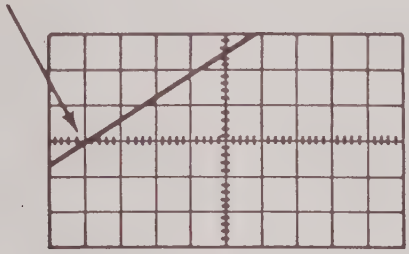


FIGURE 1.3.12

6. Record reference voltage using DVM, accurate to 1 mV.

7. Adjust comparison voltage until slope of triangle intersects next major horizontal grid mark.

8. Record accurately the new reference voltage.

9. Repeat to obtain as many points as desired.

10. Calculate linearity and observe linearity is 99% or better.

NOTE: Horizontal time base accuracy of oscilloscope and accuracy of DVM are important to obtain meaningful data.

1.3.13 SQUAREWAVE

1. INITIAL CONTROL SETTINGS

TRIGGER	RUN
SWEEP	OFF
AMPLITUDE	15 v
OFFSET	OFF
FREQUENCY	2 MHz
WAVEFORM	SQUARE

2. Connect MAIN OUTPUT terminated into 50 ohms to scope.

3. Measure transition time from 10% to 90% of peak to peak voltage to be less than 16 nSec.

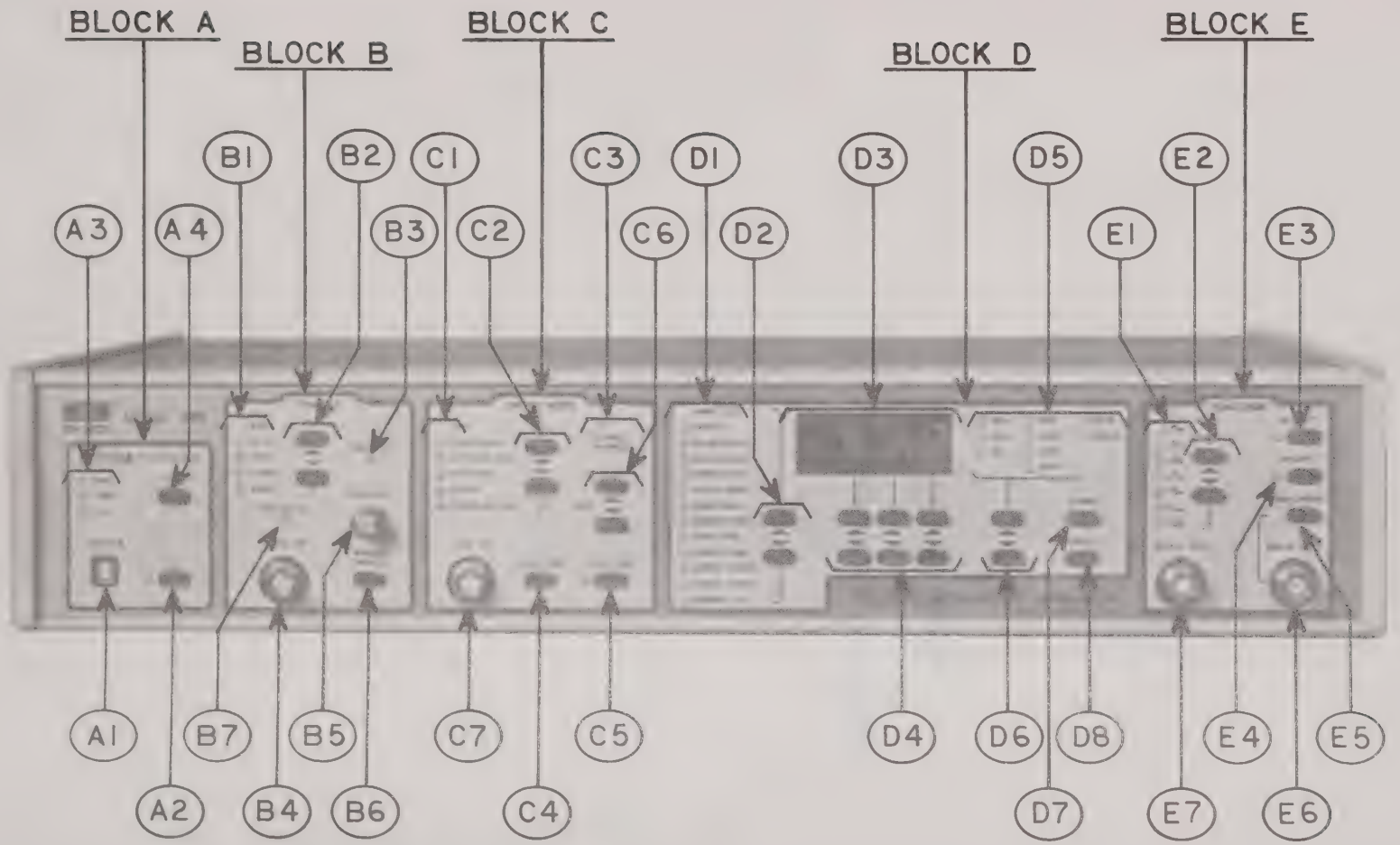
4. Measure overshoot and ringing to be less than 95 mV.

5. Select pulse. Repeat steps 3 and 4.

SECTION 2

OPERATING PROCEDURE

628



628 FRONT PANEL FAMILIARITY

FIGURE 2.1

2.1 INSTRUMENT FAMILIARITY

This section describes the controls, displays, indicators, inputs, and outputs of the Model 628. It refers to Figures 2.1 and 2.2 and also refers the user to more detailed descriptions in sections listed in parentheses.

2.1.1 FRONT PANEL

The front panel is grouped into five blocks labeled A through E.

BLOCK A - POWER/CAL/GPIB

A1. POWER SWITCH - Turns on or off power to the instrument (2.2.2).

A2. CAL SWITCH AND LED - Switch used to initiate or end an automatic calibration routine. The LED indicates that a calibration is in progress (2.12).

A3. GPIB STATUS LED's - Three LED's which indicate the current control status of the GPIB interface. They are REM - Remote, ADDR - Addressed, and SRQ - Service Request (2.3.2).

A4. LOCAL SWITCH - Returns the instrument to local front panel control unless inhibited by Local Lockout over the GPIB (2.3.2.2).

BLOCK B - TRIGGER

B1. TRIGGER MODE LED's - Five LED's which indicate the current main generator trigger mode if the SWEEP MODE is OFF, or the Sweep Trigger Mode if the SWEEP MODE is not OFF (2.4, 2.5.3.3).

B2. TRIGGER MODE SELECT SWITCHES - Two switches which select the trigger mode by stepping up or down through the five possible modes (2.4, 2.5.3.3).

B3. SWEEP ON LED - Indicates when on that the SWEEP MODE is ON (any position besides OFF) and that the entire TRIGGER BLOCK B of controls is used to trigger sweeps. When off, indicates that the SWEEP MODE is OFF and that BLOCK B is now used to trigger cycles of the main generator (2.5.3).

B4. EXTERNAL TRIGGER INPUT BNC - Input jack for an external trigger signal (2.4.1.1).

B5. TRIGGER LEVEL CONTROL - Variable control which adjusts the triggering threshold voltage level of the TRIG IN signal (2.4.1.1).

B6. MANUAL TRIGGER SWITCH - Pushbutton for manually triggering the instrument (2.4.1.2).

2.1.1 **FRONT PANEL** (CONTINUED)

B7. TRIGGER ON LED - Indicates that a trigger is present, either from the TRIG IN jack or the MANUAL TRIGGER switch. Repeated triggers are indicated by a flashing LED (2.4.1).

BLOCK C - SWEEP MODE

C1. SWEEP MODE LED's - Six LED's which indicate the current sweep mode. If the SWEEP MODE is in a position other than OFF, the SWEEP ON LED in BLOCK B will be on (2.5.3.3).

C2. SWEEP MODE SELECT SWITCHES - Two switches which select the SWEEP MODE by stepping up or down through the six possible modes (2.5.3.3).

C3. FREQUENCY MARKER LED's - Two LED's which indicate whether the current frequency is less than (<) or greater than (>) the MARKER FREQUENCY. If equal then both LED's will light. These LED's operate the same in sweep and non-sweep modes (2.5.5).

C4. LOAD FREQUENCY SWITCH - This switch transfers the current operating frequency into either the Start Frequency, Stop Frequency or Marker Frequency, whichever is being displayed at that time. If anything else is being displayed the switch does nothing (2.5.6).

C5. STOP/CONTINUE SWEEP SWITCH AND LED - This switch stops a sweep if one is in progress and holds the frequency at that point. If the sweep is already stopped, pushing the switch resumes the sweep. The LED is illuminated whenever the sweep is stopped (2.5.3.4.1).

C6. FREQUENCY STEP SWITCHES - Two switches which increment or decrement the current frequency by the amount of the Frequency Step (2.5.4).

C7. VCF, VOLTAGE CONTROLLED FREQUENCY INPUT BNC - Input jack for a control voltage which may vary the Main generator frequency (2.5.1).

BLOCK D - NUMERIC PARAMETER DISPLAY

D1. DISPLAY SELECT LED's - Thirteen LED's which indicate which parameter has been selected and is being shown on the numeric display (2.3).

D2. DISPLAY SELECT SWITCHES - Two switches which select the displayed parameter by stepping up or down through the thirteen possible parameters (2.3).

D3. NUMERICAL DISPLAY - A four digit numerical LED display which reads the value of whichever parameter has been selected (2.3).

2.1.1 **FRONT PANEL** (CONTINUED)

D4. NUMERICAL DATA ENTRY SWITCHES - Six switches which enter numerical data into the selected displayed parameter by incrementing or decrementing the number by ones, tens, or hundreds. The result includes carry into or borrow from higher digits as required. Each parameter is limited to a certain range of numeric values. If an entry would go beyond these limits it instead stops at the limit. Also, the Pulse Delay and Burst Period parameters will go down to Ø one step below their lower limits and back up to their lower limits one step up from Ø (2.3).

D5. RANGE/UNITS OF MEASUREMENT LED's - Nine LED's which indicate the units of measurement of the displayed parameter, either frequency, time or voltage, except that Burst Count and Memory/Cal do not have units (2.3).

D6. RANGE SELECT SWITCHES - Two switches which select the range for the displayed parameter by stepping up or down by a power of ten. Both the decimal point and the units LED's adjust to display the new range. Each parameter is limited to its own legal ranges. These switches do not affect Burst Count or Memory/Cal which have no units and therefore have only one range (2.3).

D7. STORE SWITCH - This switch stores the current instrument setting into one of twenty non-volatile memory locations. The memory location is designated by the number 1-2Ø present in the Memory/Cal display. The Store switch may be inhibited in certain cases by the Store Control Code (2.13), in order to protect memory contents (2.11.1).

D8. RECALL SWITCH - This switch recalls an instrument setting from a non-volatile memory location 1-2Ø designated by the Memory/Cal display. The previously stored setting including modes and parameters is loaded into the instrument's current operating conditions. The Recall switch may be inhibited in certain cases by the Recall Control Code (2.13) in order to prevent the accidental changing of instrument settings (2.11.1).

BLOCK E - FUNCTION

E1. FUNCTION /WAVEFORM LED's - Seven LED's which indicate the selected function or waveform. The functions are labelled by graphic pictures of the waveforms they represent, from top to bottom, Sine, Triangle, Haversine, Havertriangle, Square, Pulse and Double Pulse (2.6).

E2. FUNCTION SELECT SWITCHES - Two switches which select the function by stepping up and down through the seven possible waveforms (2.6).

2.1.1 **FRONT PANEL** (CONTINUED)

E3. OFFSET SWITCH AND LED - Switch used to alternately turn on and off the DC Offset added to the basic waveform, in the amount set into the numerical Offset parameter. The LED indicates that the offset is on (2.10).

E4. INVERT SWITCH AND LED - Switch used to alternately invert and re-right the waveform. The LED indicates that the waveform is inverted (2.8).

E5. FRONT/REAR SWITCH AND LED - Switch used to alternately select either the front or rear BNC jacks for the Main generator output. The LED indicates that the front jack is selected. Note that under GPIB control any combination of front and rear jacks on or off may be programmed including both on and both off. However, the front panel switch may select only one or the other on (2.9).

E6. MAIN OUTPUT FRONT BNC - Jack for the Main output when the Front jack is selected (2.9).

E7. SYNC OUTPUT BNC - Output jack for the synchronizing signal from the generator (2.6).

2.1.2 **REAR PANEL**

1. POWER INPUT MODULE - Combination device which contains the AC power input jack, the line fuse, and the line voltage selector switch (2.2.1).

2. GPIB INTERFACE CONNECTOR - Connector with jack screws for a GPIB (IEEE-488) interface cable to remotely program the instrument (2.3.2).

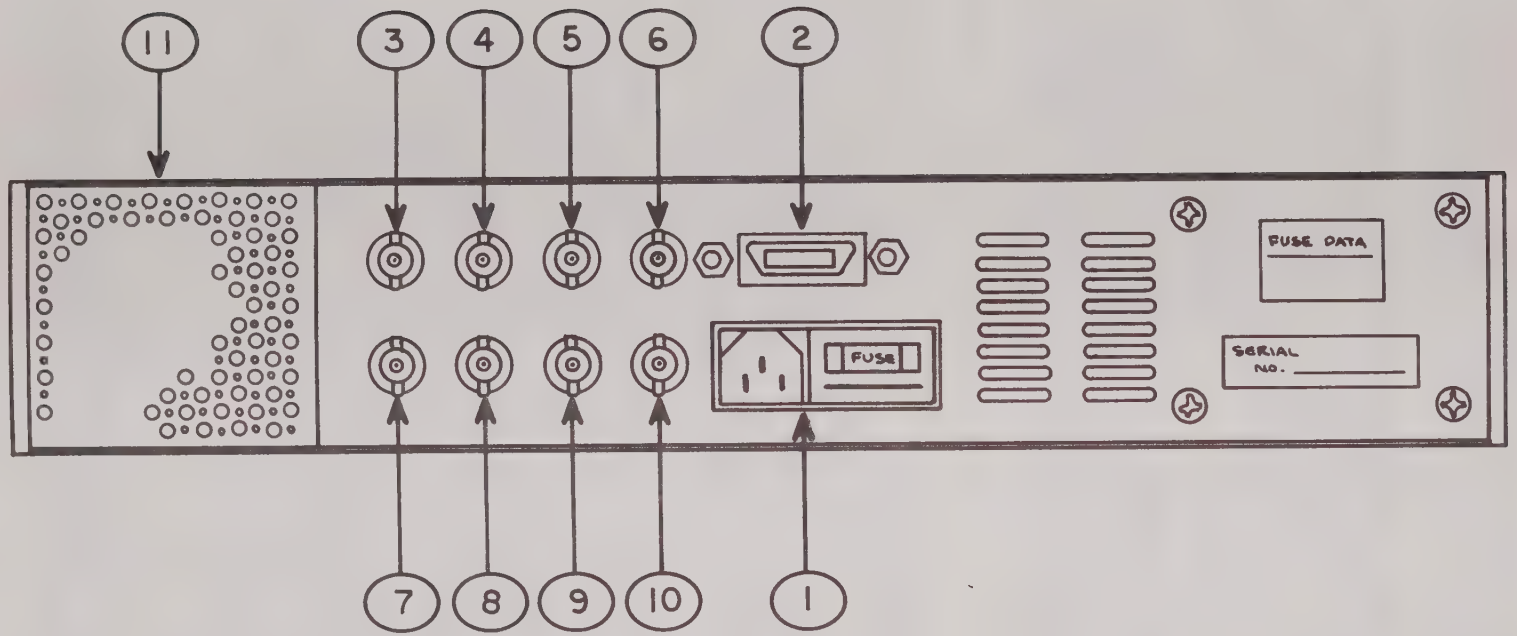
3. V:F, VOLTAGE PROPORTIONAL TO FREQUENCY OUTPUT BNC - Output jack for a signal whose voltage is proportional to the current Main generator frequency (2.5.2).

4. AMPLITUDE MODULATION INPUT BNC - Input jack for a control voltage which may vary the Main generator output amplitude (2.10.1).

5. SWEEP/BURST SYNC OUTPUT BNC - Output jack for a signal which synchronizes an internally timed sweep or burst, whichever is active (2.4.2.5, 2.5.3.5)

6. ECL PULSE OUTPUT BNC - Ouput jack for the Pulse generator signal at ECL logic levels (2.7.1).

7. MAIN GENERATOR REAR OUTPUT BNC - Output jack for the Main generator when the Rear jack is selected (2.9).



628 REAR PANEL FAMILIARITY

FIGURE 2.2

2.1.2 **REAR PANEL** (CONTINUED)

8. PULSE WIDTH MODULATION INPUT BNC - Input jack for a control voltage which may vary the width of the Pulse generator (2.7.5).

9. F>M, FREQUENCY GREATER THAN MARKER OUTPUT BNC - Output jack for a signal that indicates that the current Main generator frequency is greater than or equal to the Marker frequency. The signal is at TTL levels (2.5.5).

10. TTL PULSE OUTPUT BNC - Output jack for the Pulse generator signal at TTL logic levels (2.7.1).

11. FAN FILTER - Prevents dust from being drawn into the instrument. It should be cleaned occasionally depending on the environment. The filter may be removed by removing the single screw and the cover. It may be beaten or washed in soap and water.

2.2 POWER

2.2.1 POWER INPUT MODULE

The Model 628 uses an integral module for AC input power which contains the power connector (IEC), fuse and fuseholder, and line voltage select switch. The fuse and select switch are normally shipped in the proper configuration for the destination country, but they should be checked prior to installation.

With the power cord removed from the connector, slide the plastic cover to the left (looking at the rear panel) to expose the fuse. Remove the fuse by pulling the FUSE PULL handle. With this handle out. pull out the small PC board using a hooked instrument looped around the hole in the board. Select the nominal line voltage printed on the board (100, 120, 220 or 240) corresponding to the local line voltage. Orient the board so the selected number is at the top left position and push the board back into its slot. The selected number should now be the only number visible on the PC board. Check that the fuse is correct. It should be 1 1/2 A Slo-Blo for voltages 100-120 and 3/4 A Slo-Blo for 220-240 volts. Push back the FUSE PULL handle, reinsert the fuse and slide the cover back to the right. Plug the power cord into the connector. The instrument is now ready to be operated.

2.2.2 POWER-UP

Turn on power to the instrument by pushing in the POWER switch. On power-up the instrument will recall all parameters stored in non-volatile memory location 1 and return to that setting

2.3 INSTRUMENT SET-UP

The Model 628 may be set up to the desired operating conditions either by front panel switches or by remote control using the GPIB interface (IEEE-488).

Basic instrument set-up consists of the following steps:

1. Select one Trigger mode.
2. Select one Sweep mode.
3. Select one Function (waveform).
4. Set Offset on or off.
5. Set Invert on or off.
6. Select Main Output front or rear.
7. For the above conditions, enter data for those numeric parameters which are applicable:

   Amplitude - All conditions, except when leaving the generator untriggered with zero baseline waveforms.

   Offset - If Offset is switched on.

   Frequency - If sweep is off. (When sweep is on the Frequency display position is not used to enter data except when a sweep in progress has been stopped.)

   Start Frequency, Stop Frequency, Frequency Step, and Sweep Time - If in sweep.

   Marker Frequency - If desired.

   Burst Period and Burst Count - If in burst.

   Pulse Width and Pulse Delay - If in pulse.

   Once entered, numeric parameters remain current in the instrument even when they are not actively being displayed. Moving the display to another parameter in no way changes the parameters or the operation of the instrument.

   In some modes of operation, certain parameters may conflict with others to create an illegal conbination, even though each individual parameter is within its specified range. For example, too much Amplitude and Offset added together will clip the output power amplifier. The instrument allows numeric data entry within each parameter's specified limits even though it may result in a setup error. In this way the operator is not required to enter parameters in any particular order. Whenever a setup error occurs, various LED's will flash to indicate what the error is. In addition a service request may be generated and the error type may be interrogated over the GPIB. See Setup Errors (2.14).

2.3.1 FRONT PANEL

All of the nine pairs of up-down switches on the instrument feature a repeat action when held down. The trigger mode, sweep mode, display, and function select switches in addition will wrap around from bottom to top or vice versa after reaching their limits.

2.3.2 GPIB INTERFACE

The Model 628 is remotely programmable by the industry standard General Purpose Interface Bus (GPIB) as defined by IEEE Standard 488-1978. All instrument settings are programmable except the Trigger Level Control. In addition. some features are operable only by the GPIB.

The instrument supports the following subsets of the interface functions of IEEE 488:

SH1, AH1, T6. TE0, L4, LE0. SR1, RL1, PP0, DC1, DT1, C0, E2

2.3.2.1 GPIB ADDRESS

The instrument's GPIB address is contained in non-volatile memory (EEPROM) and therefore there are no address switches. The address has been preset at the factory to 10 but may be set to any number from 0 to 30 (decimal) by performing a Cal 19. Set the Memory/Cal number to 19. Press the Cal switch. Cal must not have been disabled by the Cal Control Code (2.13). The current GPIB address will now be displayed (with all display select LED's off). Enter the new address as a decimal number with the numerical data entry switches. Push the Store switch to store the new address. The display will return to its previous state. The same procedure is used when only needing to read the address. Pushing Store is the only way to exit the Cal 19 routine.

The Addressed LED will light whenever the instrument is addressed to either listen or talk.

2.3.2.2 REMOTE/LOCAL FUNCTION

The instrument supports the complete GPIB Remote Local Interface Function (subset RL1) which includes Local Lockout. Use the standard GPIB protocol to control the various states.

In local, all normal front panel controls are operable and the instrument will ignore device dependent messages. The instrument powers up in local control.

2.3.2.2 **REMOTE/LOCAL FUNCTION** (CONTINUED)

In remote, all front panel switches are disabled except the Power and Local switches. The instrument will now accept and allow itself to be programmed by device dependent messages on the GPIB. The Remote LED will be on. If Local Lockout is also in effect, the Local switch will be disabled. Otherwise, pushing the Local switch returns the instrument to local control.

2.3.2.3 **PROGRAMMING: LISTENER FUNCTION**

The main use of the GPIB is to program instrument settings. When in remote, and addressed to listen, device dependent messages will be received, interpreted, and converted to set into the instrument modes and parameters. A message for programming consists of an ASCII character string containing the mnemonics for the desired commands and numeric data. Besides programming the instrument, the interrogate commands tell it to prepare a message which it will transmit when addressed to talk.

2.3.2.3.1 **MESSAGE SYNTAX**

An incoming message may be up to 128 characters in length. Spaces are ignored. A message must end either with a Line Feed (LF) or by asserting the EOI line with the last message character. Carriage Returns (CR) are ignored. A message contains one or more commands. The commands may be separated by spaces, commas, or semicolons, but need not be separated. A command may be in one of three formats:

1. Instruction mnemonic only.
2. Mnemonic followed by numeric data.
3. Mnemonic followed by numeric data followed by units of measurement.

No extra characters are allowed between parts of a command (except spaces) or the rest of that command will be discarded.

The instruction mnemonics are 2-4 alphanumeric characters each. For the alphabetic characters, upper or lower case is accepted. Numeric characters in the mnemonic must be as shown and are independent of numeric data.

Numeric data is allowed in a flexible format. A number may be up to 8 digits with decimal point and may be preceded by a + or - sign. Negative numbers are used only to program Offset, otherwise this sign is ignored. The basic number may be multiplied by a power of ten as in scientific notation. The number should then be followed by an E and the exponent (power of ten). The exponent may be up to three digits and may also be preceded by a plus or minus sign.

2.3.2.3.1 **MESSAGE SYNTAX** (CONTINUED)

For certain commands, units of measurement may follow numeric data. These are optional and if omitted default as follows:

Frequencies - Hertz (HZ)
Time - Seconds (S)
Voltage - Volts (V)

Units and their symbols are defined in the following table:

SYMBOL	DEFINITION
HZ	Hertz
KHZ	Kilohertz = 10^3 Hertz
MHZ	Megahertz = 10^6 Hertz
S	Seconds
MS	Milliseconds = 10^{-3} Seconds
US	Microseconds = 10^{-6} Seconds
NS	Nanoseconds = 10^{-9} Seconds
V	Volts
MV	Millivolts = 10^{-3} Volts

For a particular parameter, the units allowed are limited to those normally used to describe the ranges of that parameter. For example, NS is allowed for Pulse Width but not for Sweep Time.

Having received a command containing numeric data, the instrument evaluates the number including exponent and units if present. If the number is found to be within the correct range for the parameter being programmed it is accepted. If not, a GPIB Numeric Data Out of Range condition is detected which may cause a service request if unmasked and the number is discarded.

An 8 digit number is accepted in order to allow for leading or trailing zeroes but once a number is processed it is truncated past the significant digits wanted for that command.

Some examples of numeric data and their processed results are shown on the chart on the next page.

2.3.2.3.1 **MESSAGE SYNTAX** (CONTINUED)

COMMAND	NUMERIC DATA	RESULT
FRQ	1234	1.234 KHZ
FRQ	1.234E6	1.234 MHZ
FRQ	1234E-03	1.234 HZ
AMP	5.678E-002	56.7 MV
AMP	1.5E+4MV	15.00 V
OFS	-75E2MV	-7.50 V
PWD	20000000NS	20.00 MS
PWD	.00002E6MS	20.00 MS

Throughout the message evaluation if an unrecognized character is found, a GPIB Syntax Error is noted which may also cause a service request if unmasked. This error does not prevent the good parts of the message from being processed, but it will indicate to the programmer that the message may not be doing its job as intended.

As well as with individual commands, most of the instrument may be programmed with one specific command, PALL (Program All).

The PALL command must be followed by a particularly formatted string of 80 digits called the Learn String.

2.3.2.4 **INTERROGATION: TALKER FUNCTION**

The instrument may be interrogated by the system controller as to the state of any of its modes or parameters. Messages are sent back to the controller. Whenever the instrument receives an interrogate command, it prepares the appropriate message to send back. Then, when it is addressed to talk it will send the message.

Note that the message is not changed until the next interrogate command is received, so if again addressed to talk, the instrument will send the same message again. On power up, a dummy message of "X" is created and kept until the first interrogation.

All interrogate command mnemonics start with the letter "I".

For modes and parameters that can be stored in the non-volatile memory locations 1-20, interrogations may be made of the current instrument setting or of a memory location. To interrogate memory, the basic interrogate command should be followed by numeric data in the general format giving the number of the memory location 1-20. If the numeric data is absent, or equals zero, or is out of the range 1-20, the current instrument setting will be queried.

2.3.2.4 **INTERROGATION: TALKER FUNCTION** (CONTINUED)

All messages sent are numeric and of various fixed formats. All messages are terminated by a Carriage Return (CR) and Line Feed (LF). The EOI line (End or Identify) is asserted with the Line Feed.

The IALL command (Interrogate All) returns the 80 character Learn String, the same as used by the PALL command. IALL may be used for current conditions or memory locations.

2.3.2.5 **SERVICE REQUEST**

A Status Byte is maintained in the instrument which is sent to the system controller whenever it asks for a Serial Poll at the instrument's address. This byte contains information on the things that may cause a Service Request and also a bit that indicates whether the instrument has actually requested service by activating the SRQ line. The Status Byte format is shown below:

STATUS BYTE

BIT NO.	8	7	6	5	4	3	2	1
DESCRIPTION	NOT USED	SRQ	NOT USED	CAL OVER	SWEEP OVER	GPIB NUMERIC DATA OUT OF RANGE	GPIB SYTAX ERROR	SETUP ERROR
BINARY WEIGHT	128	64	32	16	8	4	2	1

Bits 1-5 contain the instrument status and are at logic 1 if that condition is active. Bits 6 and 8 are not used and are always zero. Bit 7 is the Service Request bit which is generated from the other bits and the SRQ Mask Byte.

The Mask Byte is used to select which of the Status Byte bits 1-5 will be allowed to generate a Service Request. It may be programmed by the MSK command. It has the same format as the Status Byte except for bit 7. Bits 1-5 are used. A logic 1 in a Mask bit enables the corresponding status bit to generate a Service Request.

Whenever one of the bits 1-5 of the Status Byte is set to a 1, if the corresponding Mask bit is also at a 1, then the SRQ bit will be set to 1. If the Mask bit is 0, the SRQ bit is not changed.

Setting the SRQ bit to 1 also activates the hardware SRQ line to the controller. This line always reflects the condition of the SRQ bit, except that other instruments on the same bus may also pull the line.

2.3.2.5 **SERVICE REQUEST** (CONTINUED)

The SRQ LED is also lit whenever the SRQ bit is a 1.

Once set, the SRQ bit may be reset in two ways. The bit is automatically reset to Ø after the Status Byte has been read by a Serial Poll from the system controller. Also, whenever one of the Status Byte bits 1-5 is reset to Ø, all 5 bits are checked with the Mask Byte. If there are no Status bits remaining at a logic 1 whose corresponding Mask bits are also at a 1, then the SRQ bit will be reset to Ø and the SRQ line will be de-activated.

Both the Status and Mask Bytes are cleared to all zeroes on power-up.

To program the Mask Byte send the MSK command with numeric data. The number should be a decimal number Ø-31 which is the sum of the binary weights of the bits which are to be 1's. Thus 31 sets all 5 bits to 1, 12 sets bits 3 and 4 to 1 and resets bits 1, 2, and 5 to Ø, and Ø resets all bits to Ø.

The Mask Byte may be queried by the IMSK command, which will return a 2 digit decimal number of the same format.

The 5 bits of the Status Byte are controlled as follows:

BIT 1 - SETUP ERROR
This bit is set to 1 whenever there are one or more setup errors and reset to Ø when all setup errors have been eliminated. The setup error may be further interrogated with the IERR command.

BIT 2 - GPIB SYNTAX ERROR
This bit is set to 1 whenever a message is received that contains a syntax error such as an unidentified character. The bit is reset to Ø when a subsequent message is received with no syntax errors.

BIT 3 - GPIB NUMERIC DATA OUT OF RANGE
This bit is set to 1 whenever numeric data following a GPIB command is found to be out of the range of allowable numbers for that command. The bit is reset to Ø when a message is received without any such errors.

BIT 4 - SWEEP OVER
This bit is set to 1 whenever a sweep in progress is completed. It is reset to Ø when another sweep is started.

BIT 5 - CAL OVER
This bit is set to 1 whenever a Cal routine is completed and reset to Ø when a Cal routine is started.

2.3.2.6 DEVICE CLEAR

The instrument accepts Device Clear (DCL) and Selected Device Clear (SDC) commands per standard GPIB protocol. Both these commands force the instrument to its power-up state.

2.3.2.7 DEVICE TRIGGER

The instrument accepts the standard Group Execute Trigger (GET) command which will trigger the generator. Note that other trigger commands are also available over the GPIB as device dependent messages as well as an external trigger inhibit command.

2.3.2.8 THE LEARN STRING

The Learn String is a string of 80 digits formatted to contain setup information for most of the instrument modes and parameters. It is used with the PALL (Program All) and the IALL (Interrogate All) commands.

To program all these modes and parameters in one command, send PALL followed by the Learn String. One caution to note is that limited error checking is available with this command. The instrument only checks that the string contains 80 characters which are all digits. It is possible to program an illegal mode or out of range parameter if the numbers are not correct.

The IALL command may be used to interrogate the current instrument settings or those stored in non-volatile memory locations 1-20. The same format is used for other interrogate commands. Send IALL followed by the memory location number to interrogate memory. Leaving the number absent or equal to zero interrogates current settings. The instrument will send back the 80 digit Learn String.

Note that the last 2 digits of the string, which represent the Memory/Cal number always reflect the current instrument setting even if memory has been queried. This parameter is not stored in the non-volatile memory. Always returning the current setting makes the Learn String a consistent 80 characters long.

The digits in the Learn String are assigned as in the following table. The interpretations of individual modes and parameters are given in the Command Summary tables (2.3.2.9) in the IALL columns.

2.3.2.8 **THE LEARN STRING** (CONTINUED)

THE LEARN STRING

DIGITS	NO.	DESCRIPTION
1	1	TRIGGER MODE
2	1	SWEEP MODE
3	1	FUNCTION
4	1	OFFSET ON/OFF
5	1	INVERT ON/OFF
6	1	MAIN OUTPUT JACK
7,8	2	DISPLAY POSITION
9-14	6	AMPLITUDE
15-20	6	OFFSET
21-26	6	PULSE WIDTH
27-32	6	PULSE DELAY
33-38	6	FREQUENCY
39-44	6	START FREQUENCY
45-50	6	STOP FREQUENCY
51-56	6	MARKER FREQUENCY
57-62	6	FREQUENCY STEP
63-68	6	SWEEP TIME
69-74	6	BURST PERIOD
75-78	4	BURST COUNT
79,80	2	MEMORY/CAL

2.3.2.9 **COMMAND SUMMARY**

This section contains detailed descriptions of all GPIB device dependent commands. It includes mnemonics for setup and interrogate commands. ranges of instrument parameters, and formats for interrogate messages.

An interrogate command listed followed by a lower case "n" indicates that that command may be used to interrogate either current settings or memory locations.

2.3.2.9.1 **MODES**

This group of commands controls six modes of operation. These are fundamental instrument settings which are included in non-volatile memory storage. For the six types of commands, the descriptions include the following:

1. Interrogate command mnemonic and number of digits in interrogate message.
2. Digit position of IALL reply in Learn String.
3. Table listing setup commands, description, interrogate command result, and IALL command result for the assigned digit in the Learn String.

2.3.2.9.1 **MODES** (CONTINUED)

TRIGGER MODE

INTERROGATE - IMDn, 1 digit
IALLn - digit 1

SETUP COMMAND	DESCRIPTION	IMDn	IALLn
M1	RUN	1	1
M2	GATE	2	2
M3	TRIGGER	3	3
M4	INHIBIT	4	4
M5	BURST	5	5

SWEEP MODE

INTERROGATE - ISWMn, 1 digit
IALLn - digit 2

SETUP COMMAND	DESCRIPTION	ISWMn	IALLn
SW0	SWEEP OFF	0	0
SW1	CONTINUOUS	1	1
SW2	SWEEP AND HOLD	2	2
SW3	UP/DOWN	3	3
SW4	GATED	4	4
SW5	GATED UP/DOWN	5	5

FUNCTION/WAVEFORM

INTERROGATE - IWn, 1 digit
IALLn - digit 3

SETUP COMMAND	DESCRIPTION	IWn	IALLn
W1	SINE	1	1
W2	TRIANGLE	2	2
W3	HAVERSINE	3	3
W4	HAVERTRIANGLE	4	4
W5	SQUARE	5	5
W6	PULSE	6	6
W7	DOUBLE PULSE	7	7

2.3.2.9.1 **MODES** (CONTINUED)

OFFSET ON/OFF

INTERROGATE - IOFFn, 1 digit
IALLn - digit 4

SETUP COMMAND	DESCRIPTION	IOFFn	IALLn
OFF0	OFFSET OFF	0	0
OFF1	OFFSET ON	1	1

INVERT ON/OFF

INTERROGATE - INVn, 1 digit
IALLn - digit 5

SETUP COMMAND	DESCRIPTION	INVn	IALLn
NV0	INVERT OFF	0	0
NV1	INVERT ON	1	1

MAIN OUTPUT JACK FRONT/REAR

INTERROGATE - IJKn, 1 digit
IALLn - digit 6

SETUP COMMAND	DESCRIPTION	IJKn	IALLn
JK0	BOTH JACKS OFF *	0	0
JK1	FRONT ONLY ON	1	1
JK2	REAR ONLY ON	2	2
JK3	BOTH JACKSON *	3	3

* Not possible from front panel control.

2.3.2.9.2 NUMERIC PARAMETERS

THIS GROUP OF COMMANDS CONTROLS THE ENTRY OF NUMERIC DATA INTO THE THIRTEEN NUMERIC PARAMETERS OF THE INSTRUMENT. ALL NUMERIC PARAMETRERS EXCEPT THE MEMORY/CAL NUMBER ARE INCLUDED IN THE STORED INSTRUMENT SETTINGS IN NON-VOLATILE MEMORY.

FOR EACH PARAMETER THE DESCRIPTION INCLUDES THE FOLLOWING:

1. SETUP COMMAND NMEMONICS.

2. UNITS OF MEASUREMENT ALLOWED.

3. INTERROGATE COMMAND MNEMONICS AND MESSAGE FORMAT OF REPLY ("D" = DIGIT).

4. DIGIT POSITIONS OF IALL REPLY IN LEARN STRING.

5. LIMITS OF NUMERIC DISPLAY.

6. TABLE LISTING ALL RANGES AND THE FULL SCALE REPRESENTATIONS OF TH4E DISPLAY, INTERROGATE COMMAND, AND IALL. THE DISPLAY COLUMAN SHOWS DECIMAL POINT PLACEMENT AND UNITS. NOTE THAT THE INTERROGATE COMMAND GIVES A NUMERIC EXPRESSION, WITH EXPONENT. WHICH IS IMPLIED TO BE THE MOST BASIC UNITS. (HERTZ, SECONDS OR VOLTS). THE IALL COMMAND GIVES THE DISPLAY COUNT, FOLLOWED BY A RANGE NUMBER IF APPLICABLE.

WHENEVER A PARAMETER SETUP COMMAND IS RECEIVED, THE INSTRUMENT WILL MOVE THE DISPLAY TO THAT PARAMETER, EVEN IF NO NUMERIC DATA IS INCLUDED WITH THE COMMAND. IN THIS WAY IDSPN COMMAND MAY BE USED TO INTERROGATE THE DISPLAY POSITION. THE DISPLAY POSITION IS INCLUDED IN THE STORED INSTRUMENT SETTING IN NON-VOLATILE MEMORY.

SETUP COMMANDS FOLLOWED BY "N" INDICATE NUMERIC DATA MAY FOLLOW THE MNEMONIC, AND BY A "U" INDICATE THAT UNITS OF MEASUREMENT MAY BE USED.

2.3.2.9.2 **NUMERIC PARAMETERS** (CONTINUED)

AMPLITUDE

Note: Pulse amplitudes are half the amplitudes of other waveforms since they have a baseline of zero volts. The amplitude display is divided by two when entering pulse and multiplied by two when leaving. In the table, the data for pulse amplitudes is listed below the normal data for each range.

SETUP COMMAND - AMPnu
UNITS - V, MV
INTERROGATE - IAMPn, D.DDDE+D (volts)
IALLn - digits 9-14
Display limits100 TO 1500 counts, non-pulse functions
50 to 750 counts, pulse

RANGE	DISPLAY	IAMPn	IALLn
1	15.00 V	1.500 E+1	150001
	7.50 V	0.750 E+1	075001
2	1.500 V	1.500 E+0	150002
	.750 V	0.750 E+0	075002
3	150.0 MV	1.500 E-1	150003
	75.0 MV	0.750 E-1	075003

OFFSET

SETUP COMMAND - OFSnu
UNITS - V, MV
INTERROGATE - IOFSn, ±.DDDE+D (volts)
IALLn - digits 15-20
Display limits -750 to +750 counts

RANGE	DISPLAY	IOFSn	IALLn
1	7.50 V	+.750 E+1	150001
	.00 V	+.000 E+1	075001
	-7.50 V	-.750 E+1	000001
2	.750 V	+.750 E+0	150002
	.000 V	+.000 E+0	075002
	-.750 V	-.750 E+0	000002
3	75.0 MV	+.750 E-1	150003
	.0 MV	+.000 E-1	075003
	-75.0 MV	-.750 E-1	000003

Note: Data is shown for plus and minus limits and center (zero) of ranges. The IALL message (first 4 digits) is made by adding 750 to the display count in order to keep the Learn String all numeric.

2.3.2.9.2 **NUMERIC PARAMETERS** (CONTINUED)

PULSE WIDTH

SETUP COMMAND - PWDnu
UNITS - S, MS. US, NS
INTERROGATE - IPWDn, D.DDDE+D (seconds)
IALLn - digits 21-26
Display limits 180 to 2000 counts

RANGE	DISPLAY	IPWDn*	IALLn
1	2000 S	2.0000 E+3	200001
2	200.0 S	2.0000 E+2	200002
3	20.00 S	2.0000 E+1	200003
4	2.000 S	2.0000 E+0	200004
5	200.0 MS	2.0000 E-1	200005
6	20.00 MS	2.0000 E-2	200006
7	2.000 MS	2.0000 E-3	200007
8	200.0 US	2.0000 E-4	200008
9	20.00 US	2.0000 E-5	200009
10	2.000 US	2.0000 E-6	200010
11	200.0 NS	2.0000 E-7	200011

* ALSO IPDLn

PULSE DELAY

SETUP COMMAND - PDLnu
UNITS - S, MS. US, NS
INTERROGATE - IPDLn, D.DDDE+D (seconds)
IALLn - digits 27-32
Display limits 180 to 2000 counts and 0 counts

Ranges same as Pulse Width

2.3.2.9.2 **NUMERIC PARAMETERS** (CONTINUED)

FREQUENCIES

The five frequency parameters are interrelated in that they are always on the same range. They are Frequency, Start Frequency, Stop Frequency, Marker Frequency and Frequency Step. Whenever the range is changed on one of these parameters, the range of all the others is automatically changed to that range, although the display counts remain the same.

All five parameters have setup commands that control the display count and range separately. The NXXXn commands enter the numeric data, limited from 1 to 2000, into the display count without changing the range. The RXXXn commands change only the range, from 0 to 7 according to the table. Note that the range number for the RXXXn commands corresponds to the power of ten in Hertz of the full scale of that range as used by the IFRQn command.

The Frequency parameter also has a setup command, FRQnu, which includes units, which will select the best range for the data entered and may change both the display count and the range.

FREQUENCY

SETUP COMMANDS - FRQnu
NFRQn
RFRQn
UNITS - HZ, KHZ, MHZ
INTERROGATE - IFRQn, D.DDDE+D (hertz)
IALLn - digits 33-38
Display limits 1 to 2000 counts

RANGE	DISPLAY	RFRQn*	IFRQn**	IALLn
1	20.00 MHZ	7	2.000 E+7	200001
2	2.000 MHZ	6	2.000 E+6	200002
3	200.0 KHZ	5	2.000 E+5	200003
4	20.00 KHZ	4	2.000 E+4	200004
5	2.000 KHZ	3	2.000 E+3	200005
6	200.0 HZ	2	2.000 E+2	200006
7	20.00 HZ	1	2.000 E+1	200007
8	2.000 HZ	0	2.000 E+0	200008

* ALSO RSTAn, RSTPn, RMRKn, RSTEn
** ALSO ISTAn. ISTPn, IMRKn, ISTEn

2.3.2.9.2 **NUMERIC PARAMETERS** (CONTINUED)

START FREQUENCY

SETUP COMMANDS - NSTAn
RSTAn
UNITS - none
INTERROGATE - ISTAn. D.DDDE+D (hertz)
IALLn - digits 39-44
Display limits 1 to 2000 counts

Ranges same as Frequency

STOP FREQUENCY

SETUP COMMANDS - NSTPn
RSTPn
UNITS - none
INTEROGATE - ISTPn, D.DDDE+D (hertz)
IALLn - digits 45-50
Display limits 1 to 2000 counts

Ranges same as Frequency

MARKER FREQUENCY

SETUP COMMANDS - NMRKn
RMRKn
UNITS - none
INTERROGATE - IMRKn, D.DDDE+D (hertz)
IALLn - digits 51-56
Display limits 1 to 2000 counts

Ranges same as Frequency

FREQUENCY STEP

SETUP COMMANDS - NSTEn
RSTEn
UNITS - none
INTERROGATE - ISTEn, D.DDDE+D (hertz)
IALLn - digits 57-62
Display limits 1 to 2000 counts

Ranges same as Frequency

2.3.2.9.2 **NUMERIC PARAMETERS** (CONTINUED)

SWEEP TIME

SETUP COMMAND - SWTnu
UNITS - S,MS
INTERROGATE - ISWTn, D.DDDE+D (seconds)
IALLn - digits 63-68
Display limits 100 to 2000 counts

RANGE	DISPLAY	ISWTn	IALLn
1	2000 S	2.000 E+3	200001
2	200.0 S	2.000 E+2	200002
3	20.00 S	2.000 E+1	200003
4	2.000 S	2.000 E+0	200004
5	200.0 MS	2.000 E-1	200005

BURST PERIOD

SETUP COMMAND - BPRnu
UNITS - S, MS, US
INTERROGATE - IBPRn, D.DDDE+D (seconds)
IALLn - digits 69-74
Display limits 100 to 2000 and 0 counts

RANGE	DISPLAY	IBPRn	IALLn
1	2000 S	2.000 E+3	200001
2	200.0 S	2.000 E+2	200002
3	20.00 S	2.000 E+1	200003
4	2.000 S	2.000 E+0	200004
5	200.0 MS	2.000 E-1	200005
6	20.00 MS	2.000 E-2	200006
7*	2.000 MS	2.000 E-3	200007
8*	200.0 US	2.000 E-4	200008
9*	20.00 US	2.000 E-5	200009
10*	2.000 US**	2.000 E-6	200010

* Ranges 7-10 do not allow pulse waveforms.
** 0.400 US is minimum on range 10 (except 0.000 US).

BURST COUNT

SETUP COMMAND - BCTn
UNITS - none
INTERROGATE - IBCTn, DDDD
IALLn - digits 75-78
Display limits 1 to 2000 counts

Only one range with no units.

2.3.2.9.2 **NUMERIC PARAMETERS** (CONTINUED)

MEMORY/CAL NUMBER

SETUP COMMAND - MEMn
UNITS - none
INTERROGATE - IMEM, DD
IALLn - digits 79-80
(Always current setting)
Display limits 1 to 20 counts

Only one range with no units.

DISPLAY POSITION

SETUP COMMAND - Use command for each parameter without numeric data.
INTERROGATE - IDSPn, DD
IALLn - digits 7-8

DISPLAY PARAMETER	IDSPn	IALLn
AMPLITUDE	Ø1	Ø1
OFFSET	Ø2	Ø2
PULSE WIDTH	Ø3	Ø3
PULSE DELAY	Ø4	Ø4
FREQUENCY	Ø5	Ø5
START FREQUENCY	Ø6	Ø6
STOP FREQUENCY	Ø7	Ø7
MARKER FREQUENCY	Ø8	Ø8
FREQUENCY STEP	Ø9	Ø9
SWEEP TIME	10	10
BURST PERIOD	11	11
BURST COUNT	12	12
MEMORY/CAL	13	13

2.3.2.9.3 **ENABLE BNC JACKS**

These commands enable or disable certain external BNC connections. These settings are not stored in non-volatile memory, but always power-up in the enabled state. Since they may not be controlled by the front panel, they all return to the enabled state whenever the Trigger Mode is changed by a front panel pushbutton.

2.3.2.9.3 **ENABLE BNC JACKS** (CONTINUED)

EXTERNAL TRIGGER INPUT

INTERROGATE - IXTG, 1 digit

COMMAND	DESCRIPTION	IXTG
XTGØ	Disables External Trigger*	Ø
XTG1	Enables External Trigger*	1

* Includes Manual Trigger

AM INPUT

INTERROGATE - IAMD, 1 digit

COMMAND	DESCRIPTION	IAMD
AMØ	Disables AM Input	Ø
AM1	Enables AM Input	1

VCF INPUT (FM)

INTERROGATE - IFMD, 1 digit

COMMAND	DESCRIPTION	IFMD
FMØ	Disables FM (VCF) Input	Ø
FM1	Enables FM (VCF) Input	1

PWM INPUT

INTERROGATE - IPWM, 1 digit

COMMAND	DESCRIPTION	IPWM
PWMØ	Disables PWM Input	Ø
PWM1	Enables PWM Input	1

SYNC OUTPUT

INTERROGATE - ISYN, 1 digit

COMMAND	DESCRIPTION	ISYN
SYNØ	Disconnects SYNC Output	Ø
SYN1	Connects SYNC Output	1

2.3.2.9.4 TRIGGER

An auxiliary trigger command is given to set the trigger level to a true or false steady state level. This feature complements the Group Execute Trigger (GET) command which is a one shot type trigger. This trigger, called GPTR, is always reset false on power-up and whenever the Trigger Mode is changed (by GPIB or front panel). The GPTR source must be figured in with GET and External and Manual triggers to determine when the instrument will actually be triggered.

COMMAND	DESCRIPTION
TRØ	Resets GPTR trigger false
TR1	Sets GPTR trigger true

NOTE: In sweep, do not send more than one GPTR command per message, as the instrument will ignore all but the last one in any message string.

2.3.2.9.5 SETUP ERROR

INTERROGATE - IERR, DDDDDDDD

This command interrogates the eight possible groups of setup errors and replies with a string of 8 digits. Each of the 8 digits indicates the specific type of error for its group 1-8 in sequence. A Ø indicates no error for that group (2.14).

2.3.2.9.6 SERVICE REQUEST MASK

SETUP COMMAND - MSKn
INTERROGATE - IMSK, DD

These commands setup or interrogate the Service Request Mask Byte (2.3.2.5).

2.3.2.9.7 MISCELLANEOUS CONTROL

These commands control instrument operations. They perform the identical function as pushing the equivalent front panel buttons.

2.3.2.9.7 **MISCELLANEOUS CONTROL** (CONTINUED)

COMMAND	DESCRIPTION
SUP	Step Up Frequency
SDN	Step Down Frequency
SSW	Stop Sweep
CSW	Continue Sweep
LDF	Load Frequency
STO*	Store into non-volatile memory
RCL*	Recall from non-volatile memory
CAL*	Initiate (or end) auto cal routine

* Except these commands may not be inhibited by the Cal 20 Control Codes.

2.4 TRIGGER

The Model 628 is triggerable from different sources. The Trigger Mode determines the results of a trigger. When the Sweep Mode is off, a trigger may produce cycles of the basic waveform. When Sweep is on, a trigger may produce sweeps.

2.4.1 TRIGGER SOURCES

The instrument accepts triggers from five sources. To trigger the instrument, any one of the enabled sources must go true. When all enabled sources go false the instrument is untriggered. Note that leaving a trigger source true inadvertently may cause another source not to operate as expected.

2.4.1.1 EXTERNAL TRIGGER INPUT

This input allows for triggering by an external electrical signal. The input is DC coupled with an input impedance greater than 1 Kohm. The trigger goes true whenever the input is greater than the threshold voltage, adjustable from 0 to +15 Volts by the Trigger Level control. The Trigger On LED lights whenever this trigger goes true. The LED indicates repetetive triggers by flashing at a visible rate. The external trigger is disabled by the XTG0 command over the GPIB and re-enabled by the XTG1 command. It is also enabled on power-up and whenever the Trigger Mode is changed by front panel control.

2.4.1.2 MANUAL TRIGGER

The instrument may be triggered by pushing the Manual Trigger switch. This trigger source shares the Trigger On LED and is enabled or disabled along with the External Trigger by the XTG commands.

2.4.1.3 GPTR COMMANDS

This trigger source, called GPTR, is set true by the TR1 command and false by TRØ and remains in its programmed state. The GPTR is reset false on power-up and whenever the Trigger Mode is changed (by GPIB or front panel). This trigger source is not affected by the XTG commands.

2.4.1.4 GROUP EXECUTE TRIGGER (GET)

The instrument accepts the GPIB standard command GET when addressed to listen. When the GET is received, this trigger source goes true for approximately 6 microseconds. then goes false and remains false until the next GET. This trigger is not affected by the XTG commands.

2.4.1.5 INTERNAL TRIGGER

The instrument will trigger itself internally in the Burst mode (Sweep on or off) whenever the Burst Period is set up to be non-zero. This internal trigger occurs once every Burst Period. All other triggers are disabled when internal trigger is active.

2.4.2 TRIGGER MODES - SWEEP OFF

When the Sweep Mode is off, the Trigger Mode and the trigger sources determine when the Main generator is turned on and off.

When the main generator is turned off it is called "locked out" and the output will remain at the lockout level of the waveform selected.

2.4.2.1 RUN

When in the Run Mode the Main generator runs continuously and is never locked out regardless of trigger.

2.4.2.2 **GATE**

When in the Gate Mode the Main generator will run as long as it is triggered and will lock out whenever it is untriggered.

2.4.2.3 **TRIGGER**

When in the Trigger Mode the Main generator will run for one cycle only whenever it is triggered. The instrument must then be untriggered before it will generate another cycle with the next trigger.

2.4.2.4 **INHIBIT**

When in the Inhibit Mode the Main generator remains locked out regardless of triggers. This mode should be used when only a DC voltage is wanted, using Offset to set the DC level.

2.4.2.5 **BURST**

When in the Burst Mode the Main generator will run for the number of cycles N, contained in the Burst Count, whenever triggered. The instrument must be untriggered before it may generate another burst of N cycles with the next trigger. N may be 1 to 2000.

If the Burst Period is zero, the trigger source may be any except the internal trigger. If the Burst Period is not zero, all triggers except internal are disabled and the generator is triggered automatically every Burst Period.

The Burst Period may be set up from 400 nanoseconds to 2000 seconds in 10 ranges. See GPIB Command Summary (2.3.2.9) for ranges. The display limits are 100 to 2000 counts, but the display will go to 0 counts when taken below 100. In range No. 10, going below 0.400 US (except to go to 0) exceeds the minimum Burst Period for the instrument and causes an error indication (Setup Error 2-5).

In ranges 1-6, any function (waveform) may be selected, but in ranges 7-10 the internal trigger is derived from the pulse generator. Therefore, the pulse function is not available with a Burst Period in these ranges. Attempting to set up this combination also results in an error (2-3 or 2-4). In ranges 7-10, the Pulse Width Modulation input could affect the Burst Period if connected. It may be disabled by GPIB.

When using internally timed bursts, the length of the burst (Time period of a single cycle x Burst Count) must be less than the Burst Period or another error (2-1) results.

2.4.2.5 **BURST** (CONTINUED)

When internally timed Burst is active (without sweep), the rear panel Sweep/Burst Sync Output may be used to synchronize with the bursts. This TTL signal goes high coincident with the internal burst trigger. In ranges 1-6 the signal stays high for approximately 250 microseconds. In ranges 7-10 the signal stays high for one-half the burst period. This output is protected from the application of excessive voltage by a fuse. If the signal does not appear to be operating, check this fuse. See Fuses (4.4).

2.5 MAIN GENERATOR/FREQUENCY

The Main generator will operate at a frequency from .001 Hz to 20 MHz over 8 ranges. See GPIB Command Summary (2.3.2.9) for ranges. For each range the display may go from 1 to 2000 counts giving over 3 decades of variation. When sweeping or stepping up or down, the frequency always stays in the same range. Since ranges overlap it is possible to select some frequencies on any of four different ranges. Whenever possible, enter the frequency as close as possible to the full scale of a range. This practice will optimize frequency accuracy and other performance factors. The FRQ command of the GPIB does this optimization.

2.5.1 VOLTAGE CONTROLLED FREQUENCY INPUT

The Main generator base frequency may be varied by connecting a control voltage to the Voltage Controlled Frequency (VCF) Input (also called the FM Input).

The control voltage is summed with the generator's internal circuits. The frequency will vary linearly with the control voltage. A positive control voltage increases the frequency and a negative one decreases the frequency from the internal setting. The frequency will vary the equivalent of 400 counts per volt of control but must remain within the limits of 1 to 2000 on the selected range.

The VCF (FM) input is disabled by the FM0 command over GPIB and re-enabled by the FM1 command. It is enabled on power-up and whenever the Trigger Mode is changed by front panel control.

2.5.2 VOLTAGE PROPORTIONAL TO FREQUENCY OUTPUT

The voltage of the signal from the rear panel V:F output jack is proportional to the Main generator frequency. The voltage is .025V per display count so that 2000 counts full scale gives 5V output. The voltage depends on display count but not on range and includes any contribution of the VCF input.

When sweeping, the V:F output is a ramp waveform.

2.5.3 SWEEP

The instrument may be set up to sweep the Main generator frequency over a given range from the Start Frequency to the Stop Frequency. Any function may be swept including pulse.

Sweep is always over the same frequency range. All five frequency parameters (Frequency, Start Frequency, Stop Frequency, Marker Frequency and Frequency Step) are always forced into the same range. Whenever the range of one is changed, the ranges of the other four are automatically changed to match it.

A sweep is set up by entering the following:

1. Start Frequency
2. Stop Frequency
3. Frequency Step
4. Sweep Mode
5. Trigger Mode

When sweep is on, numeric data may not be entered into the Frequency display. This display is now used to monitor the generator frequency which is controlled by the sweep conditions. Even before being triggered, the frequency is forced to be at the Start Frequency. It may be changed by changing the Start Frequency but not the Frequency. During a sweep, the Frequency display is updated as fast as it can be to track the changing generator frequency. Of course, with fast sweep speeds this display becomes unreadable. When a sweep is completed and not re-triggered it is left at either the Start or Stop Frequency depending on mode. It is forced to this spot and may not be changed by Frequency but only by Start or Stop Frequency, whichever it is on. The exception is when a sweep in progress has been stopped. Then the Frequency may be changed by numeric data entry or by the Frequency Step switches or GPIB commands. These constraints apply both to front panel control and GPIB programming.

2.5.3.1 START AND STOP FREQUENCIES

The sweep starts at the Start Frequency and sweeps to the Stop Frequency. Both may be set up anywhere within the display limits 1 to 2000 so that a sweep may cover over three decades. The Stop Frequency may be either higher or lower than the Start Frequency as desired. Note however that in the Up/Down sweep modes, Up means Start to Stop and Down means Stop to Start, regardless of which is higher.

2.5.3.2 SWEEP TIME/FREQUENCY STEP

Sweep time may be entered from 10 milliseconds to 2000 seconds. Display ranges are listed with the GPIB Command Summary (2.3.2.9).

Sweeping is always performed as a series of discrete steps, step size determined by the Frequency Step parameter which has the same range and units as the other frequency parameters. With small steps, however, the sweep can be made to look continuous.

The instrument computes the time required for each step from the Start and Stop Frequencies, the Frequency Step and the Sweep Time. The Start and Stop Frequencies are both included as steps as the sweep stays at each end for one step time. The number of steps in a sweep is given by the equation:

$$\text{No. Steps} = \frac{\text{Start} - \text{Stop}}{\text{Step}} + 1$$

The calculation is done in display counts and ignores the range. If the result is not an integer, it is rounded up to the next highest integer. In this case the last step of the sweep will not be a full step but will equal the remainder required to get to the Stop Frequency. It will take the same time as a normal step however.

Keep this formula in mind when setting up sweeps with large steps with a given desired step time. For example, a sweep from 1000 to 2000 in steps of 100 takes 11 steps (not 10). So if 100 millisecond steps are desired, the Sweep Time should be set to 1.1 seconds.

The time per step is computed by dividing the Sweep Time by the number of steps. There is a minimum step time however of 300 micrseconds. When small steps and a fast Sweep Time are combined, this limit can be exceeded. The instrument compensates for this problem by doubling the step time and the step size until a step time is obtained which is 300 microseconds or greater. The Frequency Step display is not changed, so be aware that the actual step may be a multiple of the displayed step.

These methods of computing sweeps allow for maximum flexibility while remaining within the limitations of the instrument's performance.

2.5.3.2 **SWEEP/TIME/FREQUENCY STEP** (CONTINUED)

For Up/Down sweeps, the Sweep Time is for one direction only so the full up/down takes two Sweep Times.

When sweeps remain repeatedly triggered, a finite retrace time of approximately 11Ø microseconds is inserted between sweeps which is not included as part of the Sweep Time.

2.5.3.3 **TRIGGER/SWEEP MODES**

Sweep is on whenever the Sweep Mode is in any position other than Off. The Sweep On LED lights in the Trigger Mode block indicating that the Trigger capabilities of the instrument, including trigger inputs and modes, are used to trigger sweeps instead of cycles of the Main generator. The five trigger sources operate the same as with sweep off.

When sweep is on but untriggered, normally the main generator will be running except for the two Gated Sweep modes, where the generator will be locked out.

The Trigger Modes are described followed by the Sweep Modes. The two are selected in combination to obtain the desired sweep. Note: The Gate mode should not be confused with the Gated sweep modes as they operate independent of each other.

2.5.3.3.1 **RUN**

In the Run Mode sweeps run repeatedly following each other.

2.5.3.3.2 **GATE**

In the Gate Mode, sweeps run repeatedly as long as the trigger is true. At the end of each sweep the trigger is checked and if true a new sweep is initiated. If false, a new sweep is not initiated until the trigger goes true again.

2.5.3.3.3 **TRIGGER**

In the Trigger Mode, the generator makes a single sweep when triggered. Following the sweep the trigger must go false and then true again to trigger another sweep. The Sweep and Hold sweep mode is a special case which takes two triggers to start a new sweep in Trigger and Burst Modes (2.5.3.3.7).

2.5.3.3.4 **INHIBIT**

In the Inhibit Mode the generator is never allowed to sweep. The Frequency display stays at the Start Frequency. The generator runs at the Start Frequency except in the Gated and Gated Up/Down sweep modes where it remains locked out.

2.5.3.3.5 **BURST**

In the Burst Mode the generator sweeps repeatedly for a number of times N, contained in the Burst Count, whenever triggered. At the end of the burst of sweeps the trigger must go false and then true again to trigger another burst. The Sweep and Hold sweep mode is a special case here as in the Trigger Mode which takes two triggers to start a new burst of sweeps (2.5.3.3.7).

In the Up/Down and Gated Up/Down sweep modes a full up and down sweep counts as one sweep.

If the Burst Period is zero, the trigger source may be any except internal trigger. If the Burst Period is not zero, all triggers except internal are disabled and a burst of sweeps is started every Burst Period. The Burst Period must be greater than the time taken for the burst of sweeps or an error will be indicated (Setup Error 2-2).

Time = Sweep Time x N normally
Time = 2 x Sweep Time x N for up/down sweeps

2.5.3.3.6 **CONTINUOUS**

In the Continuous sweep mode the generator sweeps from the Start to Stop Frequency when triggered, then immediately jumps back to the Start Frequency. When not actively sweeping the generator always runs at the Start Frequency.

2.5.3.3.7 **SWEEP AND HOLD**

In the Sweep and Hold sweep mode the generator sweeps from the Start to Stop Frequency when triggered, then if a sweep is not to be repeated the generator holds at the Stop Frequency.

In the Gate mode a new trigger will restart the sweep at the Start Frequency.

The Trigger and Burst modes are special cases which require two triggers to restart a sweep. Having completed a sweep or burst of sweeps, the generator runs held at the Stop Frequency. With the first following trigger the generator resets and runs at the Start Frequency. The

2.5.3.3.7 **SWEEP AND HOLD**

second trigger will then restart the sweep or burst of sweeps. Note that in Trigger and Burst modes the trigger must go false and true again to get a new trigger. The Burst mode with internal trigger also takes two triggers so that a burst of sweeps happens every other burst period.

The Sweep and Hold sweep mode is useful when recording test results on a chart recorder because it won't retrace over the recorded data. The Sweep/Burst Sync signal may be used to control lifting the pen on the recorder.

2.5.3.3.8 **UP/DOWN**

In the Up/Down sweep mode the generator sweeps from the Start to Stop Frequency and immediately turns around and sweeps back to the Start Frequency. The entire sweep is counted as one sweep in the counted Burst mode. When not actively sweeping the generator always runs at the Start Frequency.

2.5.3.3.9 **GATED**

The Gated sweep mode operates like the Continuous sweep mode except that when not actively sweeping the generator remains locked out. The Frequency display still reads the Start Frequency.

2.5.3.3.10 **GATED UP/DOWN**

The Gated Up/Down sweep mode operates like the Up/Down sweep mode except that the generator locks out when not actively sweeping. The Frequency display still reads the Start Frequency.

2.5.3.4 **INTERRUPTIONS**

When the generator is actively sweeping certain things can interrupt it.

2.5.3.4.1 **STOP/CONTINUE SWEEP**

A sweep in process may be stopped and held at its current frequency by pushing the Stop/Continue button or sending the SSW command over GPIB. When stopped, the LED lights next to this switch. When stopped, the Frequency may be changed by numeric data entry or by the Frequency Step switches or GPIB commands.

2.5.3.4.1 **STOP/CONTINUE SWEEP** (CONTINUED)

When stopped, pushing the Stop/Continue switch or sending the CSW command continues the sweep where it left off.

2.5.3.4.2 **RESTART**

Changing certain instrument settings causes a sweep in progress to be restarted to its Start Frequency and its pre-triggered state. Even if a sweep is stopped it will restart. A new trigger may be required to start sweeping depending on the trigger mode. The settings which cause a restart are as follows:

1. Start Frequency
2. Stop Frequency
3. Frequency Step
4. Sweep Time
5. Trigger Mode
6. Sweep Mode, if moved through the Off position.

If the Sweep Mode is changed but not moved through Off, the sweep will continue but will change to the new mode. If the Sweep Mode is changed to Off, the Frequency stays wherever it was last.

2.5.3.5 **SWEEP SYNC**

When sweep is on, the rear panel Sweep/Burst Sync Output may be used to synchronize with sweeps. This TTL signal goes high when a sweep is in progress. It is low before and after a sweep and for approximately 110 microseconds during the retrace time between consecutive sweeps. The sweep sync signal may be used as a pen lift control for a chart recorder, especially in Sweep and Hold. This output is protected from the application of excessive voltage by a fuse. If the signal does not appear to be operating, check this fuse. See Fuses (4.4).

2.5.3.6 **SERVICE REQUEST**

Bit 4 of the GPIB Status Byte is used to indicate when a sweep is over. This bit is set to 1 whenever a sweep is completed. It is reset to 0 when another sweep is started. If unmasked by the Mask Byte, the bit will generate a GPIB Service Request (2.3.2.5).

2.5.4 STEP UP/DOWN

The main generator frequency may be incremented or decremented by the amount of the Frequency Step either by the front panel Step Up and Down switches or by the GPIB commands SUP (Step Up) and SDN (Step Down).

When sweep is off, the frequency may be stepped throughout the range of 1-2000 display counts.

When sweep is on, the frequency may be stepped in this manner only when the sweep has been stopped in process. The frequency may then be stepped only within the limits of the Start and Stop Frequencies.

2.5.5 MARKER

A Marker Frequency is provided by the instrument with both visual indicators and a TTL signal. The marker is active at all times whether sweep is on or off.

The two Frequency Marker LED's indicate whether the main generator frequency is less than (<) or greater than (>) the Marker Frequency. If they are equal both LED's will light. During sweeps, the LED's are updated as fast as possible but during fast sweeps they are unreadable.

The Frequency Greater Than Marker Output on the rear panel has a TTL level signal which is high whenever the generator frequency is greater than or equal to the Marker Frequency and low when less than the Marker. This output is protected from the application of excessive voltage by a fuse. If the signal does not appear to be operating, check this fuse. See Fuses (4.4).

2.5.6 LOAD FREQUENCY

Using either the Load Frequency switch or the GPIB command LDF, the current main generator frequency may be loaded into the Start Frequency, the Stop Frequency, or the Marker Frequency, whichever one is being displayed at that time. If anything else is displayed nothing happens.

This feature is useful when these parameters are being determined experimentally by varying the main frequency.

2.6 FUNCTION/SYNC

This section describes the five waveforms derived from the Main generator. The heart of the function generator is a triangle wave generator. The sine wave is derived from the triangle by a shaping circuit. The square wave and the sync signal are

2.6 **FUNCTION/SYNC** (CONTINUED)

derived from the level detecting comparator of the triangle generator.

When the triangle generator is untriggered, it is held at a fixed point called the lockout level.

When the Sine, Triangle or Square function is selected the basic triangle generator locks out at the center of its travel on the positive going slope (Ø°).

When Haversine or Havertriangle are selected the basic generator locks out at the most negative peak (-90° or 270°).

When triggered, the basic triangle generator always runs for an integral number of cycles starting and stopping at the lockout level.

The Sync signal and the Square waveform both are low during the positive triangle slope (-90° to +90°) and high during the negative slope (90° to 270°). The Square wave swings the full peak to peak amplitude at the main output. The Sync output signal on the front panel is at TTL levels and has a 50 ohm output impedance. The Sync output is protected from the application of excessive voltage by a fuse. If the signal does not appear to be operating, check this fuse. See Fuses (4.4).

Figure 2.3 shows the five waveforms and the sync signal including lockout levels, trigger points, and phase relationships. A triggered burst of two cycles is shown for each waveform.

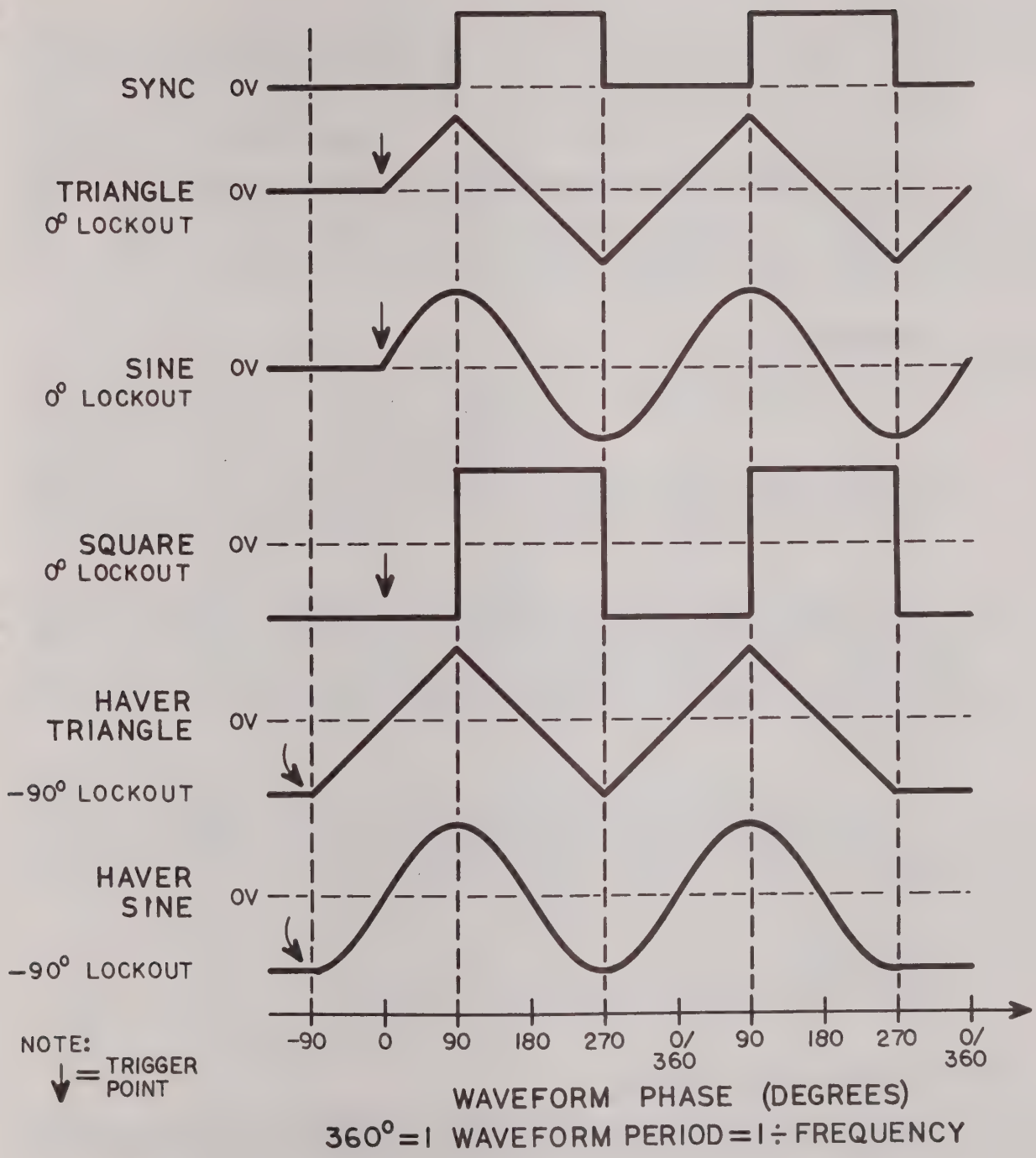

SYNC
0V
TRIANGLE
0° LOCKOUT
0V
SINE
0° LOCKOUT
0V
SQUARE
0° LOCKOUT
0V
HAVER
TRIANGLE
-90° LOCKOUT
0V
HAVER
SINE
-90° LOCKOUT
0V
NOTE:
↓ = TRIGGER POINT
-90
0
90
180
270
0/
360
90
180
270
0/
360
WAVEFORM PHASE (DEGREES)
360° = 1 WAVEFORM PERIOD = 1 ÷ FREQUENCY

FIGURE 2.3

2.7 PULSE

The instrument includes a pulse generating capability which includes variable pulse width and delay, double pulse, and pulse width modulation. Both Pulse Width and Delay may be selected from 18 nanoseconds to 2000 seconds in 11 ranges. The ranges are listed with the GPIB Command Summary (2.3.2.9). The two parameters are independent and may be in different ranges. The display limits for Pulse Width and Delay are 180 to 2000 counts to allow for some overlap between ranges. In addition, the Pulse Delay goes to 0 counts as a means of turning off the delay.

2.7.1 OUTPUTS/SYNC

Pulses are available at the main outputs with amplitude and offset control and also at the TTL and ECL rear panel outputs.

The TTL and ECL Pulse outputs are logic signals of their respective families, normally low with a high level during the pulse width. When an Inverted waveform is selected these outputs will be normally high and go low for the pulse width.

The Sync Output is a TTL level signal which changes operation when a pulse function is selected. This signal is now used to synchronize pulses with delays. In single pulse mode with delay or double pulse, the Sync signal is high during the pulse delay time. In the single pulse mode without delay the Sync signal goes high with the pulse signal but is a narrow width.

The three outputs TTL and ECL Pulse, and Sync have a 50 ohm output impedance. All are protected from the application of excessive voltage by fuses. If any of the signals do not appear to be operating, check the appropriate fuse. See Fuses (4.4).

2.7.2 PULSE MODES

Three modes of pulse operation are possible.

2.7.2.1 SINGLE PULSE, NO DELAY

When the Single Pulse function is selected and the Pulse Delay is set to 0, single undelayed pulses will be generated when triggered.

2.7.2.2 SINGLE DELAYED PULSE

When the Single Pulse function is selected and the Pulse Delay is not Ø, single pulses will be generated when triggered which are delayed from the trigger by the amount of the Pulse Delay.

2.7.2.3 DOUBLE PULSE

When the Double Pulse function is selected, two pulses of equal width are generated. The first comes immediately on triggering and the second is delayed from the trigger by the amount of the Pulse Delay. Therefore, the leading edge of the two pulses are separated by the Pulse Delay time.

In Double Pulse, the Pulse Delay must be greater than the Pulse Width or an error will be indicated (Setup Error 3-1).

2.7.3 TRIGGERING/REPETITION RATE

The pulse generator is triggered differently depending on the Trigger Mode. Of course. in Inhibit Mode it is never triggered.

When the Trigger Mode is in Trigger, one pulse is generated every time the instrument is triggered (for this discussion "one pulse" means one single pulse with or without delay or one double pulse, whichever is selected). The trigger source may be any except internal trigger and must conform to the normal triggering rules. In this mode the trigger signal is fed directly to the pulse generator, bypassing the main generator to reduce unwanted delays.

When the Trigger Mode is in Run, Gate, or Burst the pulse generator is triggered from the main generator. This is also true for all Trigger Modes when sweep is on. In these modes all rules for triggering the main generator apply. Pulses may be generated continuously in Run mode, turned on and off in the Gate mode, or bursted for 1 to 2ØØØ counts in the Burst Mode. Pulses may even be swept, resulting in pulses with a constant width but changing repetition rate.

The pulse repetition rate is equal to the main generator frequency.

The internal trigger to the pulse generator is derived from the basic triangle generator at the heart of the instrument. The trigger happens when the triangle reaches its positive peak and switches to a negative slope. In Gate and Burst Modes the main generator is triggered first and must run for one fourth of a cycle before triggering

2.7.3 **TRIGGER/REPETITION RATE** (CONTINUED)

the pulse generator. So if synchronizing to an internal trigger signal or to the Burst Sync signal an extra delay of one fourth the time period of the main generator will occur before the Pulse Sync signal.

In these modes the total time of the Pulse Width plus Pulse Delay must be less then the period of the main generator or an error will be noted (setup Errors 4 or 5).

2.7.4 **AMPLITUDE**

The main output in pulse has a zero baseline (not including offset) unlike other waveforms. The Amplitude in pulse represents the peak of the pulse, positive for non-inverted and negative for inverted waveforms. The maximum pulse amplitude is 7.5 volts which is half of that for other waveforms. To make the display consistent, the numeric Amplitude parameter is divided by two when a pulse function is entered from another function and multiplied by two when leaving a pulse function to enter a non-pulse function. For example, start with Offset off and a square wave of 10V amplitude. The main output swings from -5 to +5 volts. Move to pulse. Now the Amplitude automatically is changed to read 5V and the output swings from 0 to +5 volts.

Offset may be added to the pulse waveform the same as other waveforms.

2.7.5 **PULSE WIDTH MODULATION**

The pulse width may be varied by connecting a control voltage to the Pulse Width Modulation (PWM) input on the rear panel.

Pulse width modulation may be used on pulse width ranges 6-11, nominal width from 18 nanoseconds to 20 milliseconds. This feature has no effect on ranges 1-5 (18mS to 2000 S) because these ranges use computer timers to stretch the length of the instrument's analog circuits in order to obtain the long pulse widths.

A positive control voltage decreases the pulse width and a negative control voltage increases the plulse width. The amount of change of the pulse width varies inversely with the control voltage.

2.8 INVERT

Waveforms may be inverted and re-righted by the Invert switch or by the GPIB command NV1 and NV0. The Invert LED when on indicates that the waveform is inverted. Inverted waveforms may be recognized because they start off in a negative direction when triggered. Haverwaveforms lock out at the positive peak instead of the negative.

Pulses at the main output always have a zero baseline and have a positive peak when not inverted and a negative peak when inverted. At the TTL and ECL outputs, non-inverted pulses start at a low logic level and go to a high level during the pulse width. Inverted pulses are normally at the high level and go low during the pulse width.

The timing relationships between triggers, the waveforms, and sync pulses are not affected by inverting. These relationships are tied to the internal non-inverted triangle wave at the heart of the instrument.

2.9 MAIN OUTPUTS

The instrument has both front and rear main outputs. Either one may be selected alternately by the Front/Rear switch. The LED is on whenever the front output jack is selected. Under GPIB control the jacks are selected by the JK0, JK1, JK2, and JK3 commands. See GPIB Command Summary (2.3.2.9). Any combination of jacks on or off may be selected by the GPIB.

The instrument output amplifier is shared by the two output jacks. The output source impedance is 50 ohms. To obtain the best waveform quality, especially at high frequencies, only one output should be used at a time and it should be terminated at its destination with a 50 ohm load to ground. Instrument specifications for waveform quality and for Amplitude and Offset voltages are for this configuration. When the output is connected to a high impedance the Amplitude and Offset voltages are double the displayed values.

The output amplifier is protected from the application of excessive voltage by a clamp circuit and also by a fuse for each output jack. If either output jack does not appear to be operating check the fuse. See Fuses (4.4).

2.10 AMPLITUDE/OFFSET

The main output peak to peak Amplitude may be varied from 10 millivolts to 15 volts. Waveforms are centered around zero volts, not including DC offset. Pulses are the exception as they have a zero baseline. Their peak to peak Amplitude which

2.10 **AMPLITUDE/OFFSET** (CONTINUED)

is the same as their zero to peak Amplitude varies from .5 millivolts to 7.5 volts. To make the display consistent, the Amplitude parameter is divided by two automatically when a pulse function is entered from a non-pulse function and multiplied by two when leaving a pulse function to enter a non-pulse function.

A DC Offset voltage from -7.5 volts to +7.5 volts may be added to the basic waveform at the main outputs. The numeric Offset parameter contains the amount of offset voltage. Offset is turned on or off by the Offset switch or the GPIB command OFF1 and OFF0. The Offset LED indicates that the Offset is turned on.

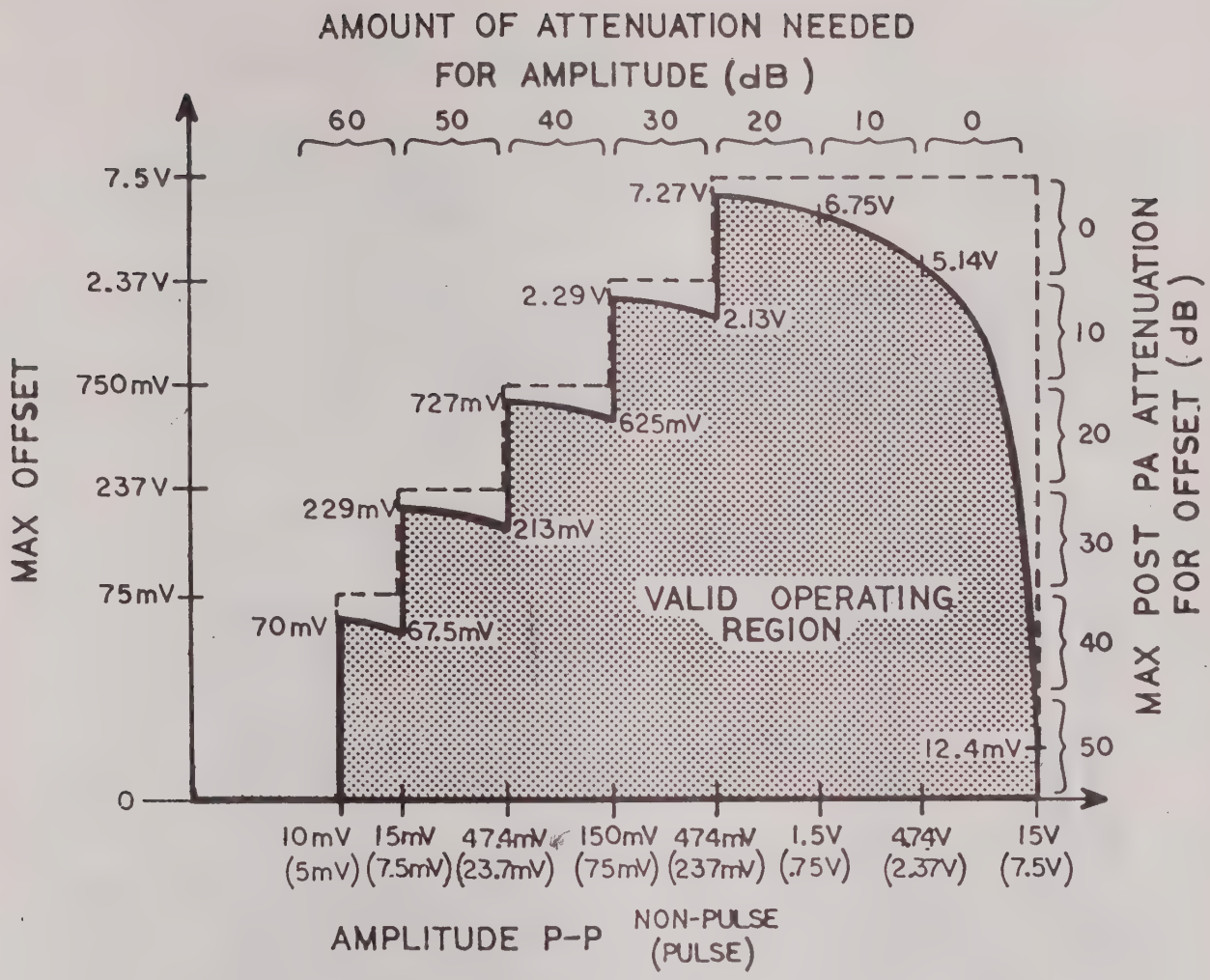
For both Amplitude and Offset, the displayed amount is the correct value when the main output is terminated with a 50 ohm load to ground. When the main output is unloaded, its Amplitude and Offset voltages are actually twice the displayed amount.

Display ranges for Amplitude and Offset are listed with the GPIB Command Summary (2.3.2.9). Note that these display ranges are converted by the instrument to its own internal attenuator ranges and therefore it makes no difference what display ranges are used for these parameters.

When Offset is added to the basic waveform it is possible to exceed the instrument's capabilities in two different ways, causing setup error indications. First, the addition of Amplitude and Offset voltages may result in a waveform which exceeds the voltage limits of the output Power Amplifier (PA) (Setup Error 1-1). Second, for a given amount of Offset, the Amplitude may be too small (Error 1-2). Figure 2.4 shows the approximate limits of combinations of Amplitude and Offset which are obtainable. Note that pulses have different positive and negative limits since they are not symmetrical to start with.

The exception is in Inhibit Mode where the sum of the lockout level and offset may be 7.5 volts in either polarity.

The maximum offset boundary is stepped because of the scheme used by the instrument to obtain the full range of amplitudes. Figure 2.5 shows a block diagram of the ciruit. The instrument controls the amplitude by selecting certain attenuators and varying the Amplitude Control circuit through a 10dB range. Total adjustment range is 0dB to -63.5dB or 15 volts to 10 millivolts (non-pulse waveforms).



THE GRAPH INDICATES MAXIMUM OFFSET ALLOWABLE FOR A GIVEN AMOUNT OF AMPLITUDE:

A) NON-PULSE WAVEFORMS MAY HAVE POSITIVE OR NEGATIVE OFFSET TO THE SOLID LINE.

B) NON-INVERTED PULSE WAVEFORM MAY HAVE POSITIVE OFFSET TO THE SOLID LINE OR NEGATIVE OFFSET TO THE DASHED LINE.

C) INVERTED PULSE WAVEFORMS MAY HAVE POSITIVE OFFSET TO THE DASHED LINE OR NEGATIVE OFFSET TO THE SOLID LINE.

VALID LIMITS OF OPERATING REGION FOR AMPLITUDE/ OFFSET COMBINATIONS
FIGURE 2.4

AMPLITUDE AND OFFSET CONTROL BLOCK DIAGRAM

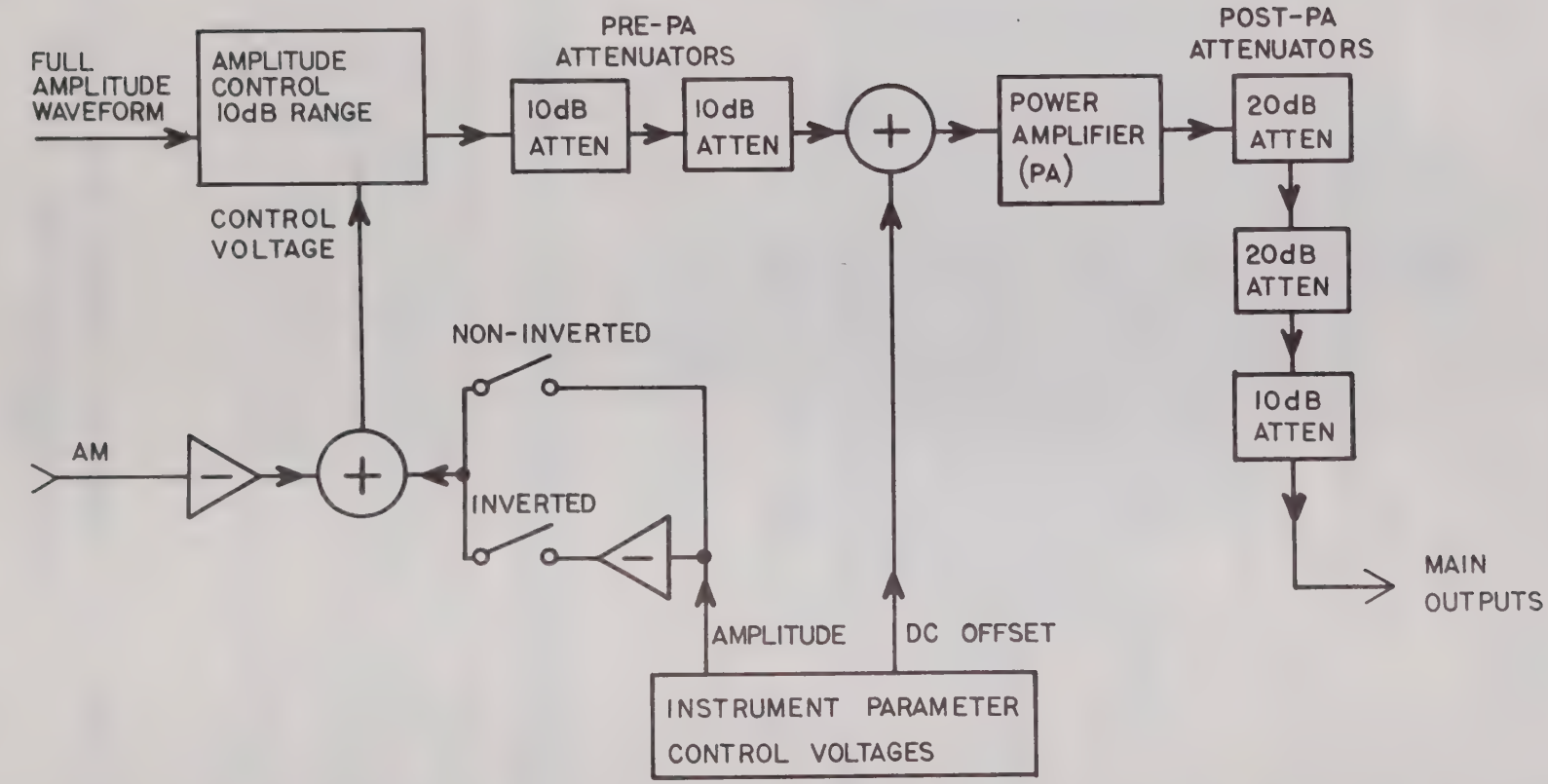


FIGURE 2.5

2.10 AMPLITUDE/OFFSET (CONTINUED)

NOTE: 0dB refers to a full scale amplitude. Every 10dB of attenuation divides the full scale amplitude by the square root of 10. For example, a -30dB signal is full scale divided by the square root of 10^3 or 31.63.

Whenever the Amplitude or Offset is changed, the instrument computes the configuration of attenuators and control voltages to get the desired results. The Amplitude attenuator range is determined as in Table 2.1 and attenuators are selected to get in that range, starting with the Post-PA attenuators. The Amplitude control voltage is calculated to get the right amplitude within that range.

When Offset is added, too many Post-PA attentuators may not be used or the Offset may not be obtainable. Table 2.2 shows the maximum amount of Post-PA attenuation possible for different amounts of Offset. If necessary, the instrument will substitute Pre-PA attenuators for Post-PA (up to 20dB). The amplitude attenuation may not exceed the maximum offset Post-PA attenuation by more than 20dB or an error will be indicated (Error 1-2). If this happens, the Offset will prevail and will be output correctly while the amplitude will be the minimum possible. This error occurs in Figure 2.4 when the boundary is exceeded horizontally to the left.

Another error is caused when the waveform created by the addition of amplitude and offset voltages exceeds the voltage limits of the Power Amplifier (PA) (Error 1-1). If possible, the instrument will substitute Pre-PA attenuators for Post-PA to stay within limits. This error occurs in Figure 2.4 when the boundary is exceeded vertically. When this error condition happens the resultant waveform will be clipped.

2.10.1 AMPLITUDE MODULATION

The amplitude of the waveform may be varied by a control voltage connected to the AM input. A positive control voltage decreases the amplitude of a non-inverted waveform and increases the amplitude off an inverted waveform. A negative control voltage increases the amplitude of a non-inverted waveform and decreases the amplitude of an inverted waveform. The amplitude changes linearly with the control voltage.

The amplitude may be decreased to zero (100% modulation) and continued past zero to invert the original waveform and increase the amplitude.

AMPLITUDE ATTENUATOR RANGES

ATTEN RANGE -dB	NON-PULSE AMPLITUDE RANGE LO	NON-PULSE AMPLITUDE RANGE HI	PULSE AMPLITUDE RANGE LO	PULSE AMPLITUDE RANGE HI
0	4.75 V	15 V	2.38 mV	7.5 V
10	1.501 V	4.74 V	751 mV	2.37 V
20	475 mV	1.5 V	238 mV	750 mV
30	150.1 mV	474 mV	75.1 mV	237 mV
40	47.5 mV	150 mV	23.8 mV	75 mV
50	15.1 mV	47.4 mV	7.6 mV	23.7 mV
60	10 mV	15 mV	5 mV	7.5 mV

Table indicates the amount of attenuation required to obtain amplitudes within the ranges shown.

TABLE 2.1

OFFSET MAXIMUM POST PA ATTENUATOR RANGES

POST ATTEN RANGE -dB	OFFSET RANGE LO	OFFSET RANGE HI
0	2.38 V	7.5 V
10	751 mV	2.37 V
20	238 mV	750 mV
30	75.1 mV	237 mV
40	23.8 mV	75 mV
50	0 mV	23.7 mV

Table indicates the maximum amount of post PA attenuation that may be used and still obtain offset within the ranges shown.

TABLE 2.2

2.10.1 **AMPLITUDE/OFFSET** (CONTINUED)

The upper limit of amplitude when modulated is the upper limit of the attenuator range, which is determined from the numeric Amplitude setting, see Table 2.1. When using AM, pick a base Amplitude in a range which includes the maximum amplitude desired when modulated. This upper limit also applies to waveforms modulated greater than 100% (inverted).

2.11 MEMORY

The instrument includes a non-volatile memory (EEPROM) which retains its contents even when power is turned off. This memory is used to store instrument settings, calibration values, control codes, and the GPIB address.

This memory has a useful life of 10,000 storage cycles for each separate location. Ordinarily, this will be plenty for several years of use. However, it is possible under GPIB control to store repeatedly if the controller program is in a loop. This situation should be avoided. There is no limit on recall cycles.

2.11.1 INSTRUMENT SETTINGS

The instrument has the capacity to store and recall 20 settings of its modes and parameters.

The memory location for these settings is selected (1-20) by the numeric Memory/Cal parameter.

An instrument setting is stored into the selected location with the Store switch or the GPIB command STO. Storing takes about 2 seconds and blanks the display. A setting is recalled from the selected location by the Recall switch or the RCL command. Recalling a setting loads all previously stored modes and parameters into the current operating conditions.

The stored setting includes the following:

MODES - Trigger Mode
Sweep Mode
Function (Waveform)
Offset on/off
Invert on/off
Main Output jack
Display Position

2.11.1 **INSTRUMENT SETTINGS** (CONTINUED)

PARAMETERS - Amplitude
Offset
Pulse Width
Pulse Delay
Frequency
Start Frequency
Stop Frequency
Marker Frequency
Frequency Step
Sweep Time
Burst Period
Burst Count

Storage and recall by the front panel switches may be inhibited under certain conditions by the Control Codes (2.13). This prevents accidental loss of data. The Control Codes do not affect the STO and RCL commands of the GPIB, however.

The Memory/Cal number need not be currently displayed in order to store or recall unless required by the Control Codes. The numeric display position is stored along with the instrument setting. In this way the setting may be recalled with the display at the most desired position for that setting.

The contents of memory may be read over the GPIB by the Interrogate commands (2.3.2.4).

When the instrument is powered-up it recalls the setting stored in location 1. A provision is made for initializing the instrument if a raw unprogrammed EEPROM is installed or if location 1 inadvertently is loaded with "garbage". If switch 1 of the internal DIP switch on the top PC board is on, the instrument will bypass location 1 and power-up into a known good state. Location 1 should then be loaded before power is turned off and DIP switch 1 is turned off. See DIP Switch (2.15).

2.12 SELF CALIBRATION

The Model 628 features the ability to measure its own frequency, symmetry, pulse width, pulse delay, amplitude, offset and lockout level and can adjust itself to optimize these parameters. Several automatic calibration routines are provided. The Memory/Cal numeric parameter selects the calibration routine to be performed. The routine is entered by pushing the Cal switch or sending the Cal command over the GPIB. The Cal LED comes on when the routine is in progress.

2.12 SELF CALIBRATION (CONTINUED)

The Cal switch may be inhibited under certain conditions by the Cal Control Code (2.13). This may prevent accidental calibrations. The code does not affect the GPIB Cal command.

Two types of calibration routines are available. Normally, when switch 3 of the internal DIP switch is off, the User Cal routines are selected. When switch 3 is on, the Factory Cal routines are performed. Factory Cal is described in Section 3. The instrument is shipped with User Cal selected which is described here. See DIP switch (2.15).

Sometimes a User Cal routine will change the waveform, frequency, and/or amplitude temporarily in order to make measurements. When it does, normally the main and sync outputs are turned off so as not to disrupt whatever may be connected. However, if switch 4 of the internal DIP switch is on, these outputs are left connected so the routines may be observed. See DIP switch (2.15). The instrument is shipped with DIP switch 4 off.

2.12.1. SERVICE REQUEST

Bit 5 of the GPIB Status Byte is used to indicate when a calibration routine is over. This bit is set to a 1 whenever a Cal routine ends. It is reset to 1 Ø when another Cal routine starts. If unmasked by the Mask Byte, the bit will generate a GPIB Service Request (2.3.2.5).

2.12.2 USER CAL ROUTINES

The User Cal routines are described here by number. Also refer to the notes following.

CAL 1: OFF
Ends the Cal 2 routine which runs continuously.

CAL 2: CONTINUOUS FREQUENCY CAL
Continuously adjusts the frequency for best accuracy. Operates only in Run Mode with sweep off. Inhibits the VCF input. This routine stays on until ended by Cal 1.

CAL 3: FREQUENCY CAL ON DEMAND
Adjusts the frequency one time only. Operates in any Trigger Mode but sweep must be off. Also adjusts the lockout level if applicable to current conditions.

CAL 4: FREQUENCY RANGE CAL
Adjusts the current frequency range for best fit accuracy over the whole range. Also adjusts the waveform symmetry.

2.12.2 **USER CAL ROUTINES** (CONTINUED)

CAL 5: PULSE CAL
Adjusts the pulse width and delay times.

CAL 6: AMPLITUDE CAL
Adjusts all amplitude parameters for the selected waveform including peak to peak amplitude. lockout level, and DC offset.

CAL 7-9: NOT USED

CAL 10: LED TEST
Turns on all LED's and numeric digit segments on the front panel for five seconds.

CAL 11: SUPER CAL
Calibrates all instrument parameters as follows:
- Frequency - All ranges and waveforms
- Symmetry
- Pulse Width and Delay
- Amplitude - All waveforms
- Lockout Level - All waveforms
- DC Offset

Stores all generated constants in non-volatile EEPROM memory. Takes about 10 minutes.

CAL 12: ERASE
Erases all calibration constants generated by Cals 2-6 since the last instrument power-up or Super Cal (Cal 11). Returns to constants stored in non-volatile EEPROM memory.

CAL 13-18: NOT USED

CAL 19: GPIB ADDRESS
Enters the GPIB address into non-volatile memory (2.3.2.1).

CAL 20: CONTROL CODES
Enters the Cal, Store, and Recall Control Codes into non-volatile memory (2.13).

NOTES:

1. Calibration constants generated by Cals 2 and 3 are used at the current frequency only and for as long as the instrument stays at that frequency and function. When the frequency or function is changed the instrument reverts to the constants previously used for that frequency range with that function.

2.12.2 **USER CAL ROUTINES** (CONTINUED)

NOTES: (CONTINUED)

The range constants use the best fit method for all frequencies over that range. Cal 2 or 3 must be used to improve on an individual frequency accuracy within a range. If the frequency is changed while Cal 2 is on, the instrument will first revert to the range constants and then continue with the Cal 2 routine. See Note 5.

2. Cals 2 and 3 only operate at frequencies of 1 Hz and above. If a Cal 2 or 3 is attempted at a lower frequency or with an incorrect mode an error is indicated (Setup Errors 8-2 and 8-3).

3. When a Cal routine is active the Cal LED lights. Except for Cal 2, the instrument will not accept any input from front panel switches or the GPIB when a Cal is active. When Cal 2 is active. the instrument alternately calibrates the frequency and then delays for one second. Front panel switch and GPIB inputs are only accepted during the one second delay. This should not drastically alter operation, but is noticeable sometimes. Occasionally a pushed switch will be missed by the instrument. When a key is held down for repeating, the display will be seen to pause during the calibration time. GPIB commands may be delayed if they arrive at that time.

4. Calibration constants generated by a Cal 11 Super Cal are stored permanently in non-volatile EEPROM memory. When the instrument is powered-up, these constants are used. Constants generated by Cals 4, 5 and 6 are kept active as long as power remains on but are lost when power is turned off. Since Super Cal constants are permanently stored it is recommended that the instrument be warmed up for one hour before performing a Cal 11.

5. Because of the instrument's internal characteristics different calibration constants are used for different functions (waveforms) for frequency, amplitude and lockout level.

In frequency, three categories of functions are calibrated separately. They are:

1) Sine and Haversine
2) Triangle and Havertriangle
3) Square and Pulse

Also. the 8 frequency ranges are calibrated separately for a total of 24 combinations. Cal 4 only calibrates the combination currently selected. Cal 11 calibrates all combinations.

2.12.2 **USER CAL ROUTINES** (CONTINUED)

NOTES: (CONTINUED)

In amplitude, four categories of functions are calibrated separately. They are:

1) Sine and Haversine
2) Triangle and Havertriangle
3) Square
4) Pulse

Also, non-inverted and inverted waveforms are calibrated separately for a total of 8 combinations. Cal 6 calibrates only the combination currently selected. Cal 11 calibrates all combinations.

Lockout level is calibrated separately for three categories of functions. They are:

1) Sine
2) Triangle
3) Haversine and Havertriangle

Square and Pulse lockout levels do not require calibration. Cal 6 calibrates the selected category only. Cal 11 calibrates all categories.

Symmetry, Pulse Width, Pulse Delay and Offset are good for the entire instrument whenever they are calibrated.

6. Cals 19 and 20 may not be performed from the GPIB.

2.13 CONTROL CODES

The Control Codes are used to inhibit the Cal, Store and Recall switches under certain conditions. This feature allows for the protection of memory locations, calibration constants and instrument setup from accidental changes.

A separate code number, from 0 to 3 is used for Cal, Store and Recall. The code numbers are entered with the User Cal 20 function and are saved in non-volatile EEPROM memory.

The code numbers 0 to 3 are defined as follows:

CODE 0 : Switch enabled.

CODE 1 : Switch enabled only when the Memory/Cal numeric parameter is actively displayed and disabled when any other numeric parameter is displayed.

CODE 2 : Switch enabled for Memory/Cal numbers 1 through 10 and disabled for Memory/Cal numbers 11 through 20.

2.13 CONTROL CODES (CONTINUED)

CODE 3 : Switch disabled.

NOTE: The exception is if the Cal Control Code = 2 or 3 and User Cal 20 is attempted, the instrument will act as if the Cal Control Code = 1 for this operation. User Cal 20 is never completely disabled because then the Control Codes could never be changed.

The Control Codes do not affect the GPIB commands CAL, STO, and RCL nor Factory Cal.

To enter the Control Codes set the Memory/Cal number to 20 and push the Cal switch. The display will now show the Control Codes as a 3 digit decimal number. The left digit is the Cal Control Code. The middle digit is the Store Control Code, and the right digit is the Recall Control Code. Note that the display treats this 3 digit number as any other number and will blank leading zeroes. The number may look like only 1 or 2 digits. Enter the new Control Codes with the data entry switches by selecting a 3 digit decimal number with each digit set as desired. Push the Store switch to store the Control Codes. The display will return to its previous state. If Control Codes greater than 3 are entered the instrument will interpret them as 3's.

The same procedure is used when only needing to read the Control Codes. Pushing Store is the only way to exit the Cal 20 routine.

2.14 SETUP ERRORS

In some modes of operation, certain parameters may conflict with others to create an illegal combination. This may occur even though each individual parameter is within it own specified limits. The instrument allows entry of numeric data within a parameter's limits at any time regardless of any other parameter's current setting. In this way the operator is not required to enter parameters in any particular order. When an illegal combination is programmed it is called a Setup Error. Various LED's will flash on the front panel to indicate the type of error.

2.14.1 SERVICE REQUEST

Bit 1 of the GPIB Status Byte is set to 1 whenever one or more Setup Errors are present. It is reset to 0 when all errors have been eliminated. If unmasked by the Mask Byte, the bit will generate a GPIB Service Request (2.3.2.5).

2.14.2 INTERROGATE ERROR

The state of all possible Setup Errors may be interrogated over the GPIB by the IERR command. The instrument will return a string of 8 digits. The digits represent the states of the 8 categories of errors. in order, from 1 to 8. Their meaning is listed in the Error Summary.

2.14.3 ERROR SUMMARY

The conditions that can cause errors are defined here in 8 categories. The number of the detailed description within each category is the number returned in the IERR string for that digit. When GPIB is not used, the flashing LED's will give clues as to the category and type of error.

ERROR 1 : AMPLITUDE/OFFSET

Amplitude and Offset are incompatible for each other, except in Inhibit Mode.

Ø = No error
1 = Amplitude added to Offset exceeds limits of Power Amplifier.
2 = Amplifier too small for the amount of Offset.

ERROR 2 : BURST

Burst Period not compatible with other settings, only in Burst Mode with internal trigger (Burst Period ≠ Ø).

Ø = No error
1 = Sweep off. Burst Period ≤ N·T, where N = Burst Count and T = time period of main generator (T = 1/Frequency).
2 = Sweep on. Burst Period ≤ N·T, where N = Burst Count and T = Sweep Time.
3 = Single Pulse function selected and Burst Period in one of ranges 6-9.
4 = Double Pulse function selected and Burst Period in one of ranges 6-9.
5 = Burst Period < 400 nanoseconds.

ERROR 3 : DOUBLE PULSE

Ø = No error
1 = Double Pulse function selected and Pulse Delay ≤ Pulse Width, except in Inhibit Mode.

2.14.3 **ERROR SUMMARY** (CONTINUED)

ERROR 4 : PULSE, SWEEP OFF

Pulse Width + Pulse Delay $\geq$ T, where T = time period of main generator (T = 1/Frequency), except in Trigger or Inhibit Modes. Sweep is off.

Ø = No error
1 = Single Pulse function selected, Pulse Delay = Ø.
2 = Single Pulse function selected, Pulse Delay $\neq$ Ø.
3 = Double Pulse function selected.

ERROR 5 : PULSE, SWEEP ON

Pulse Width + Pulse Delay $\geq$ T, where T = smallest time period at which main generator will run during sweep (T = smallest of 1/Start Frequency or 1/Stop Frequency). Sweep is on.

Ø = No error
1 = Stop Freq. > Start Freq., Single Pulse, Pulse Delay = Ø.
2 = Stop Freq. > Start Freq., Single Pulse, Pulse Delay $\neq$ Ø.
3 = Stop Freq. > Start Freq., Double Pulse
5 = Start Freq. > Stop Freq., Single Pulse, Pulse Delay = Ø.
6 = Start Freq. > Stop Freq., Single Pulse, Pulse Delay $\neq$ Ø.
7 = Start Freq. > Stop Freq., Double Pulse

ERROR 6 : SWEEP TIME

Sweep Time < T, where T = largest time period at which main generator will run during sweep (T = largest of 1/Start Frequency or 1/Stop Frequency). Sweep is on.

Ø = No error
1 = Stop Freq. > Start Freq.
2 = Start Freq. > Stop Freq.

ERROR 7 : FREQUENCY STEP

Ø = No error
1 = Frequency Step > Sweep Width, where Sweep Width is the distance swept, in frequency (Sweep Width = Stop Freq. - Start Freq.). Sweep is on.

Sweep width = Absolute Value (Stop Freq. -Start Freq.)

2.14.3 **ERROR SUMMARY** (CONTINUED)

ERROR 8 : USER CAL

User Cal 2 or 3 attempted with Frequency < 1 Hz or wrong mode selected.

Ø = No error
2 = Cal 2 attempted. Frequency < 1 Hz or sweep on or not in Run mode.
3 = Cal 3 attempted. Frequency < 1 Hz or sweep on.

2.15 DIP SWITCH

Internal to the instrument on the non-component side of the top PC board there is a miniature DIP (Dual In-line Package) switch which contains four separate switches. They are all shipped from the factory in the off position. The top cover of the instrument must be removed to switch them. When the switches are on, the instrument's operation is changed as follows:

SWITCH 1 : On power-up, the instrument will enter a known good state instead of recalling the settings in Memory location 1.

SWITCH 2 : On power-up, the instrument will initialize most calibration constants to a raw condition. This should not be done unless prepared to perform a Factory Calibration.

SWITCH 3 : Changes calibration routines to Factory Cal instead of User Cal.

SWITCH 4 : Keeps the outputs from being turned off during User Cal so the Cal routines may be observed.

2.16 SUMMARY SHEET

Figure 2.6 is a single sheet which lists the GPIB setup commands for the model 628. It also contains short descriptions of the Status Byte, Setup Errors, User Cal Routines, Control Codes, IEEE-488 Subsets and DIP Switch. This sheet is meant to be a quick reference guide.

MODEL 628 SUMMARY SHEET

TRIGGER MODE
M1 Run
M2 Gate
M3 Trigger
M4 Inhibit
M5 Burst

SWEEP MODE
SWØ Sweep Off
SW1 Continuous
SW2 Sweep and Hold
SW3 Up/Down
SW4 Gated
SW5 Gated Up/Down

FUNCTION/WAVEFORM
W1 Sine
W2 Triangle
W3 Haversine
W4 Havertriangle
W5 Square
W6 Pulse
W7 Double Pulse

OFFSET ON/OFF
OFFØ Offset Off
OFF1 Offset On

INVERT ON/OFF
NVØ Invert Off
NV1 Invert On

MAIN OUT JACK
JKØ Both Off
JK1 Front
JK2 Rear
JK3 Both On

USER CAL ROUTINES
1 Turns off Cal 2
2 Continuous Frequency
3 Frequency On Demand
4 Frequency Range
5 Pulse
6 Amplitude
11 Supercal
12 Erase
19 GPIB Address
2Ø Control Codes

IEEE-488 SUBSETS
SH1, AH1, T6, TEØ, L4,
LEØ, SR1, RL1, PPØ,
DC1, DT1, CØ, E2

NUMERIC PARAMETERS
AMPnu Amplitude V,MV
OFSnu Offset V,MV
PWDnu Pulse Width S,MS,US,NS
PDLnu Pulse Delay S,MS,US,NS
FRQnu Frequency HZ,KHZ,MHZ
NFRQn Frequency Number
RFRQn Frequency Range
NSTAn Start Freq Number
RSTAn Start Freq Range
NSTPn Stop Freq Number
RSTPn Stop Freq Range
NMRKn Marker Freq Number
RMRKn Marker Freq Range
NSTEn Freq Step Number
RSTEn Freq Step Range
SWTnu Sweep Time S,MS
BPRnu Burst Period S,MS,US
BCTn Burst Count
MEMn Memory/Cal

SERVICE REQUEST
MSKn Mask Byte

STATUS BYTE BITS/WEIGHT

1	Setup Error	1
2	GPIB Syntax Error	2
3	GPIB Numeric Data	4
4	Sweep Over	8
5	Cal Over	16
6	Not Used	32
7	SRQ	64
8	Not Used	128

SETUP ERRORS, IERR
1 Amplitude/Offset
2 Burst
3 Double Pulse
4 Pulse
5 Pulse w/Sweep
6 Sweep Time
7 Frequency Step
8 User Cal

DIP SWITCH
1 Initializes Instrument Settings
2 Initializes Calibration Constants
3 Selects Factory Cal
4 Enables Main Out for User Cal

CONTROL CODES
Left Digit - Cal Switch
Middle Digit - Store Switch
Right Digit - Recall Switch

Code Ø - Enables
Code 1 - Enabled only when Mem/Cal Displayed
Code 2 - Enabled only for Mem/Cal 1-1Ø
Code 3 - Disabled

EXTERNAL TRIGGER
XTGØ Disable
XTG1 Enable

AM INPUT
AMØ Disable
AMI Enable

VCF(FM) INPUT
FMØ Disable
FM1 Enable

PWM INPUT
PWMØ Disable
PWM1 Enable

SYNC OUTPUT
SYNØ Disable
SYN1 Enable

GPTR TRIGGER
TRØ Resets to False
TR1 Sets to True

MISC. CONTROL
SUP Step Up Freq
SDN Step Down Freq.
SSW Stop Sweep
CSW Continue Sweep
LDF Load Freq.
STO Store
RCL Recall
CAL Calibrate

FIGURE 2.6

SECTION 3

CALIBRATION PROCEDURE

3.1 INTRODUCTION

The calibration procedure in this section refers to Factory Cal and should not be confused with the User Cal routines (2.12). Factory Cal routines are selected by setting switch 3 of the top PCB DIP switch to on (2.15). In this position when the Cal button is pushed, a Factory Cal routine is entered instead of a User Cal routine.

A complete procedure is included for initializing and calibrating a new instrument as it would be at the factory. In this case the Initial Set Up (3.2), the Calibration (3.3), and Final Set Up (3.4) should be performed.

In practice in the field, the Initial Set Up (3.2) is only required to be performed if the EEPROM (U45 on top PCB) is changed or erased. Then the Calibration (3.3) and Final Set Up (3.4) will also need to be done.

Always remember that powering up an instrument with DIP switch 2 in the on position results in initializing most calibration constants in non-volatile memory to a raw condition. Afterwards at least a Shortcut Auto Cal (3.5) must be performed followed by Final Set Up (3.4).

The Shortcut Auto Cal combines all the automatic calibration routines so if no manual adjustments (pots) are to be performed, then it may be substituted for the longer calibration procedure. It should be followed by the Final Set Up.

If the manual adjustments are to be performed then then the full Calibration (3.3) should be done followed by Final Set Up (3.4).

3.1.1 EQUIPMENT REQUIRED

Oscilloscope: DC to 200MHz with differential comparator.

Frequency counter: 10Hz to 20MHz with time interval A to B.

Digital voltmeter: 4 1/2 digit. AC and DC volts.

Harmonic distortion analyzer: 0.1% residual distortion.

3.2 INITIAL SET UP

1. Set the appropriate line voltage by pulling out the card behind the fuse and reinserting it with the proper voltage visible. Install a fuse of value stated on rear panel.

3.2 **INITIAL SET UP** (CONTINUED)

2. INITIAL POWER UP

This step should be skipped if previously stored instrument set-ups are to be saved.

a. Set dip switches 1 and 2 on the top PCB on and 3 and 4 off.

b. Turn the power on. If it is already on, turn it off and on again. Wait about 10 seconds for the front panel to come up to the initial conditions as stated in the **OPERATING PROCEDURE.**

c. Set dip switches 1 and 2 on top PCB off.

d. Check that the MEMORY/CAL number is 1. Then reset the parameter display to FREQ and depress STORE.

e. Increment MEMORY/CAL to 3. Depress STORE.

f. Repeat Step e for all MEM/CAL locations up through 20. This will prevent accidentally calling up an undefined set-up.

g. Set MEM/CAL to 2. Set BURST PERIOD TO 50mSec. Set Parameter Display to BURST COUNT. Set TRIGGER to BURST. Depress STORE.

h. Set MEMORY/CAL to 19. Depress CAL. Set the displayed number (GPIB address) to 10. Depress STORE.

i. Set MEMORY/CAL to 20. Depress CAL. Set the displayed number (control code) to 0. Depress STORE.

3.3 **CALIBRATION**

Allow one hour warm up time with covers on before calibrating.

Instrument settings for the calibration procedure are stored in the 628. When the unit is in the Factory-Cal mode (dip swith 3 on) the number displayed in MEMORY/CAL corresponds to the step in this procedure. When following the procedure step by step, instrument settings and step number are incremented by depressing STOP/CONT. If it is desired to access one particular step, depress LOAD FREQ to get out of the Cal Mode and set the desired step number in MEMORY/CAL and depress CAL. To get out of the Factory-Cal mode, depress LOAD FREQ. Some calibration steps cause error indications on the front panel, ignore them.

3.3 **CALIBRATION** (CONTINUED)

Refer to Figure 3.1 and 3.2 for location of calibration points. Adjustments and Test points are on the bottom PCB unless noted.

1. +15V,D/A REF and 1MHz ADJ

   a. Set dip switch 3 on top PCB on.

   b. Set MEMORY/CAL to 1.

   c. Depress CAL.

   d. Connect DVM from TP 3 and TP 2 (com).

   e. Adjust R63 for +15V ±15 mV

   f. Connect DVM to TP 2 and TP 1 (com) on top PCB. Adjusts R43 on top Pcb for 4V ±10mV.

   g. Connect counter to TP 4 and TP 3 (com) on top PCB. Adjust C43 on top PCB for 1MHz ±10 Hz.

2. TRIANGLE BUFFER OFFSET

   a. Depress STOP/CONT once and wait a few seconds for the display to increment to 2.

   b. Connect scope to TP 4 and TP 2 (com).

   c. The scope displays approximagtely 1 2V P-P, 1KHz triangle. Adjust R42 to center the triangle about 0V ±100mV

3. TIME SYMMETRY

   a. Depress STOP/CONT and wait for the unit to automatically calibrate time symmetry. When it is done, the cal light will flash. It takes about 30 seconds and can be watched on the OUTPUT.

4. SINE DISTORTION

   a. Depress STOP/CONT.

   b. Connect OUTPUT terminated in 50 Ohm to distortion analyzer. The output waveform is approximately a 1KHz 10V P-P sinewave.

   c. Adjust R242, R370 and R433 for minimum distortion, typically <.25%.

   d. Center R154, R181 and R178 if the unit has not been previously calibrated.

3.3 **CALIBRATION** (CONTINUED)

5. 20MHz LINEARITY

   a. Depress STOP/CONT.

   b. Connect OUTPUT, terminated in 50 Ohm, to counter. OUTPUT is a 10V p-p squarewave at 20MHz.

   c. Turn R30 and R31 on the top PCB fully counterclockwise.

   d. Set FREQUENCY to 2MHz on the 20MHz range and adjust C170 for 2MHz ±.01MHz.

   e. Set FREQUENCY to 10MHz and adjust C176 for 10MHz ±.05MHz.

   f. Repeat Steps d. and e.

   g. Set FREQUENCY to 18MHz and adjust R30 on the top PCB for 18MHz ±.09MHz. If it won't adjust, turn R31 on top PCB until R30 is in range.

   h. Set FREQUENCY to 20MHz and adjust R31 for 20MHz ±.1MHz.

   i. Repeat Steps g. and h.

   j. Repeat Steps d. through i. until no more improvement can be obtained. These adjustments may be used at other frequencies than specified to improve linearity if needed.

6. FREQUENCY RANGES

   a. Depress STOP/CONT. The unit will automatically calibrate all frequency ranges. When it is done the CAL light will flash. It takes about 3 minutes and can be observed on the OUTPUT.

7. 20mSec PULSE CAL

   a. Depress STOP/CONT. The unit will automatically calibrate the 20mSec pulse width and delay ranges. It takes about 10 seconds.

8. 200nSec PULSE

   a. Depress STOP/CONT.

   b. Connect TTL PULSE, on rear panel, terminated in 50 Ohm, to counter. Set the counter trigger levels to 50% of waveform.

3.3 **CALIBRATION** (CONTINUED)

c. Adjust C75 for a 200nSec PULSE ±2nSec.

d. Connect SYNC OUT, terminated in 50 Ohm, to counter and adjust C65 for a 200nSec PULSE ±2nSec.

c. Adjust the output voltage for 0V ±20mV using the Value Select Switches only.

d. Depress STORE.

e. Steps c. and d. may be repeated if necessary.

9. 0 VOLTS REFERENCE
   a. Depress STOP/CONT.

   b. Connect OUTPUT to DVM.

   c. Adjust the output voltage for 0V ±20mV using the Value Select Switches only.

   d. Depress STORE.

   e. Steps c. and d. may be repeated if necessary.

10. +12 VOLTS REFERENCE
   a. Depress STOP/CONT.

   b. Adjust the output voltage for +12V ±20mV using the Value Select Switches only.

   c. Depress STORE.

   d. Steps b. and c. may be repeated if necessary.

11. -12 VOLTS REFERENCE
   a. Depress STOP/CONT.

   b. Adjust the output voltage for -12V ±20mV using the Value Select Switches.
   c. Depress STORE.
   d. Steps b. and c. may be repeated if necessary.

12. AMPLITUDE BALANCE
   a. Depress STOP/CONT. The unit will automatically calibrate amplitude balance. When it is done the CAL light will flash. It takes about 45 seconds and can be watched on the scope.

13. PRE ATTENUATOR ADJUST
   a. Depress STOP/Cont.
   b. Connect OUTPUT, unterminated, to scope. Observe an approximately 2V p-p squarewave. The 628 display reads 2. Set the 628 to read 0 using the numerical data entry switches only. Observe a 20V p-p squarewave. The two waveforms will not be centered about 0V but will have some offset. Adjust R154 for both waveforms to have equal offset voltages, ±100mV

3.3 **CALIBRATION** (CONTINUED)

EXAMPLE METHOD:

Set scope controls so the 20V p-p squarewave covers the entire screen vertically. Set the 628 display to 2 and center this waveform on scope screen using vertical position only. Return 628 display to 0 and center the waveform on the scope screen using R154 only. Repeat until no further improvement can be obtained.

c. Connect OUTPUT, unterminated, to DVM set to measure AC only.

d. Set 628 display to 2 and measure the voltage.

e. Set 628 display to 1 and adjust R178 for 3.162 times the voltage measured in Step d., ±30mV. The display may be stepped back to 2 to measure the voltage again.

f. Set 628 display to 0 and adjust R181 for 10 times the voltage measured in Step d., ±100mV.

14. AMPLITUDE ADJUST

a. Depress STOP/CONT and wait for the cal light to flash, about 7 minutes. The 628 is automatically calibrating all amplitude and DC levels. This can be observed on OUTPUT.

15. POST PA ATTENTUATORS

a. Depress STOP/CONT.

b. Connect OUTPUT, unterminated, to DVM set to measure AC only. Measure the voltage (approximately 15V).

c. Terminate the OUTPUT into 50 Ohm ±.2% and adjust R315 located on lower PCB for half the voltage measured in Step b., ±35mV.

d. Set the 628 display to 1 and adjust A26R16 (located in attenuator PCB) for the voltage measured in Step c. divided by 3.162, ±25mV.

e. Set the 628 display to 2 and adjust A26R10 (located on attenuator PCB) for one tenth the voltage measured in Step c., ±10mV.

f. Set the 628 display to 3 and adjust A26R13 (located on attenuator PCB) for the same voltage as in Step e., ±10mV.

16. HIGH FREQUENCY SQUAREWAVE

a. Depress STOP/CONT.

3.3 **CALIBRATION** (CONTINUED)

b. Connect OUTPUT, terminated into 50 Ohm, to scope and adjust R83 for the best compromise of overshoot and rise time. Overshoot should be <±.75 Volts and the rise time should be <16nSec.

c. Depress LEAD FREQ to exit and complete the calibration.

3.4 **FINAL SET UP**

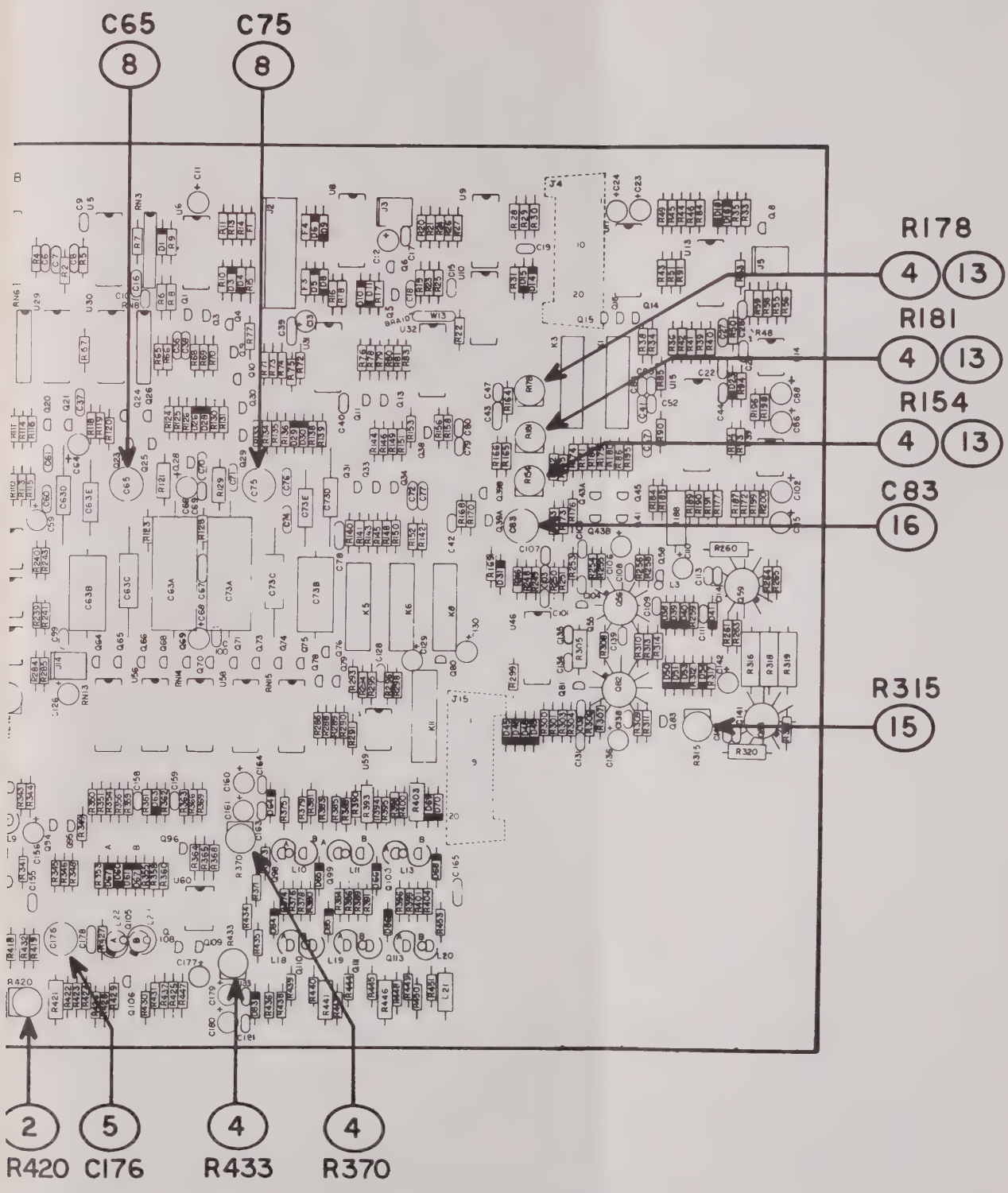
1. Return all dip switches on the top PCB to the off position. Switch 4 may be left on if it is desired to have the OUTPUT enabled during all USER CALS.

2. After complete assembly of instrument, run it for an hour. Then perform a USER CAL 11 (SUPER CAL) BY SETTING MEMORY/CAL to all 11 depressing CAL. It takes about 10 minutes.

3.5 **SHORTCUT AUTO CAL - CAL 20**

Factory Cal 20 is a combination of all the fully automatic Factory Cal routines, namely 3, 6, 7, 12 and 14. It takes about 11 minutes.

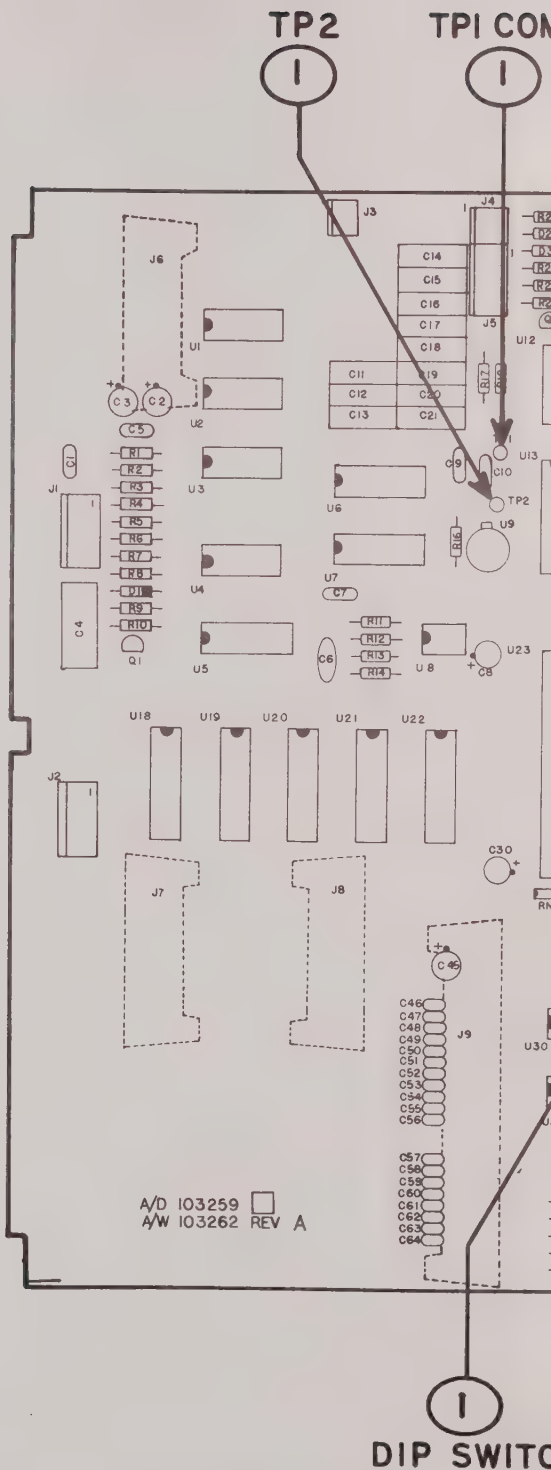
628 A2 BOTTOM PC



B ADJUSTMENT LOCATION DETAIL

FIGURE 3.1

103359-3 SHT1 REV B


TP2
TPI CON
J3
J4
J6
J5
U12
C14
C15
C16
C17
C18
C11
C12
C13
C19
C20
C21
U1
U2
C3
C2
C5
R1
R2
R3
R4
R5
R6
R7
R8
D1
R9
R10
C1
J1
U3
U6
U13
C9
C10
TP2
U9
R16
U7
C7
C4
Q1
U5
C6
R11
R12
R13
R14
U8
C8
U23
U18
U19
U20
U21
U22
J2
C30
J7
J8
C45
C46
C47
C48
C49
C50
C51
C52
C53
C54
C55
C56
J9
U30
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C58
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C61
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C63
C64
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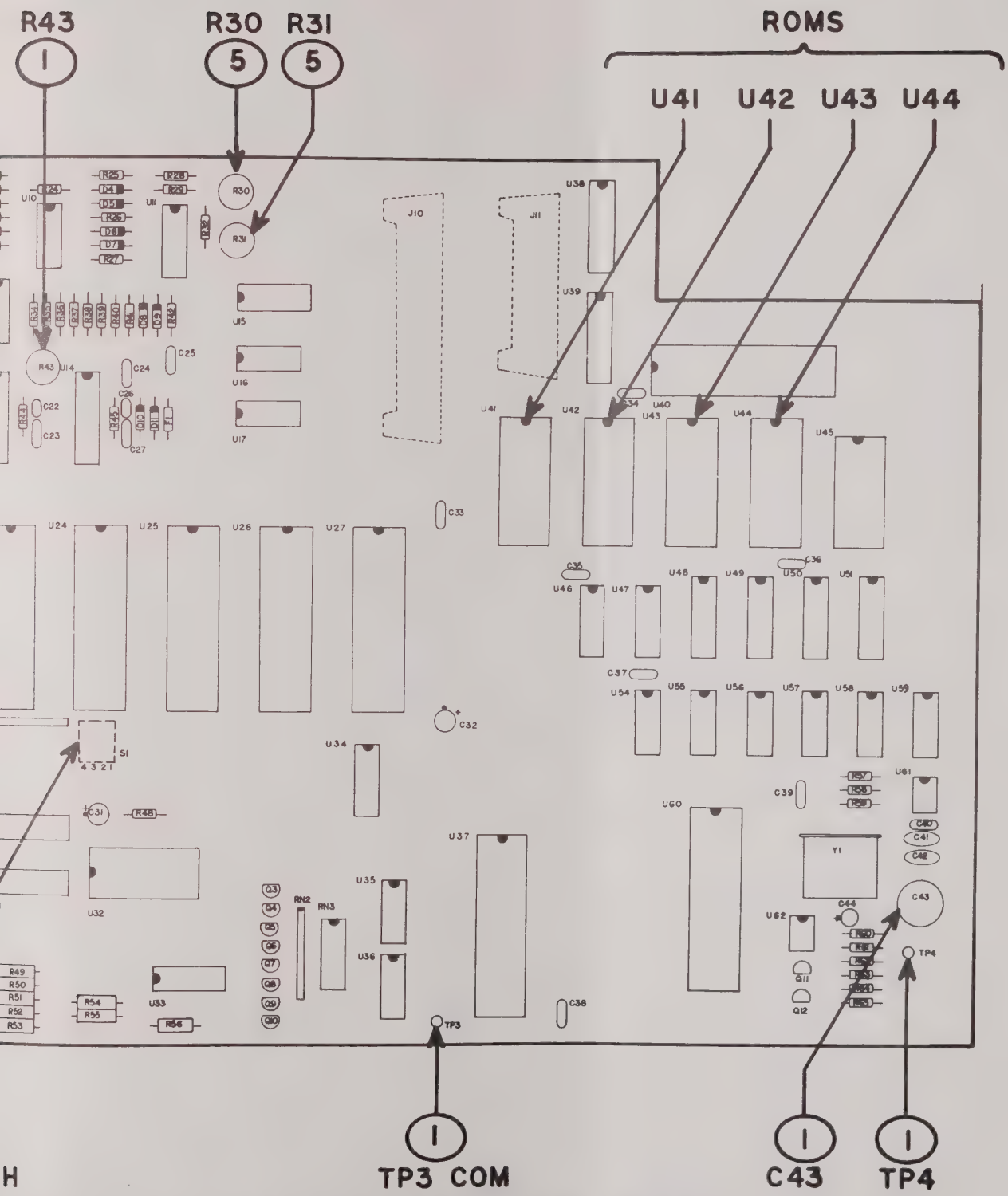
A/W 103262 REV A
DIP SWITC

628 A2 TOP



H

PCB ADJUSTMENT LOCATION DETAIL

FIGURE 3.2

103359-3 SHT2 REV A

SECTION 4

THEORY OF OPERATION

4.1 INTRODUCTION

Model 628 is a multi-featured instrument which combines a 20 MHz function generator with a pulse generator. It contains a microprocessor system which keeps track of all operating modes and parameters and controls the generator circuits. This arrangement allows the instrument to be controlled remotely through a GPIB (IEEE-488) interface as well as from the front panel. It also facilitates the addition of features such as sweep, burst and auto-calibration.

The circuitry is contained on 3 printed circuit boards. The bottom PCB is mounted fixed in the instrument and contains the power supply and generator circuits. The top PCB is hinged on the right side for access to the instrument. It contains the computer circuits and digital/analog converters. The front PCB holds the pushbutton switches, LED's and numeric displays.

4.2 BLOCK DIAGRAM

The Block Diagram shows the interaction of the various circuits and is used to explain the overall working of the instrument.

4.2.1 TOP PCB

4.2.1.1 MICROPROCESSOR

The microprocessor controls the entire instrument. It runs a dedicated program contained in EPROM'S. Also included are RAM's for temporary storage and an EEPROM for non-volatile storage of instrument settings and calibration constants.

The microprocessor continuously runs the program which controls all the I/O parts connected to it. It converts the instrument settings entered by either the front panel or GPIB to all the appropriate control lines and voltages. It also sets up several timers which it is programmed to respond to in real time for certain functions. Up to 5 timers may be running simultaneously interrupting the microprocessor. These timers control updating of multiplexed analog voltage channels, time the sweep changes and burst triggers and generate extra long pulse width and delay signals. In addition the microprocessor computes the calibration adjustments needed after measuring both frequency and amplitude.

4.2.1.2 FRONT PANEL INTERFACE

The front panel interface controls both the pushbutton switches and the LED displays of the front panel. It contains strobe and return lines for switch multiplexing and anode and cathode drivers for the LED's.

4.2.1.3 GPIB INTERFACE AND CONNECTOR

The GPIB interface controls data transfers to and from the GPIB bus allowing for the setup of the instrument by remote control. It keeps track of the states of various interface functions according to the standard protocol of IEEE-488.

4.2.1.4 DIGITAL CONTROL LINES

These are simply digital signals from I/O ports which control various generator circuits such as frequency range, waveform select attenuators, trigger mode, pulse width and delay range, invert and inputs and outputs.

4.2.1.5 DIGITAL TO ANALOG CONVERTERS

The instrument contains 2, 12 bit digital to analog converters. One is used to control the main generator frequency and the other is multiplexed to 11 channels of control voltages.

4.2.1.6 FREQUENCY CONTROL

The frequency control for the main generator is derived from its own dedicated D/A converter so it can be changed rapidly by the microprocessor to make sweeps. The D/A current is summed with a current derived from the VCF input to make a control current sent to the current sources on the bottom PCB main generator circuit.

4.2.1.7 ANALOG CONTROL CHANNELS

The second D/A converter feeds an 11 channel sample and hold multiplexer which is continuously updated by the microprocessor, creating 11 control voltages, used to control various analog instrument parameters. They are amplitude, offset, pulse width and delay, lockout level, and several calibration adjustments.

4.2.1.8 PEAK DETECTOR

The peak detector generates a voltage proportional to the plus or minus peak of the waveform. It connects to an A/D converter controlled by the microprocessor. This circuit is used to measure the waveform amplitude during calibration.

4.2.1.9 COUNTER/TIMER

The counter/timer is a circuit which measures the timing parameters of the waveform such as frequency, symmetry and pulse width and delay.

4.2.2 FRONT PCB

The front contains the pushbutton switches used to enter instrument settings and single LED's and numeric displays for displaying current instrument parameters and modes.

4.2.3 BOTTOM PCB

4.2.3.1 MAIN GENERATOR

The frequency control circuit's output is used to control two current sources. There is a positive and a negative current source. The positive current source is twice the negative one. The currents are summed on the FREQUENCY RANGE CAPACITOR. The positive current can be switched on or off by the CURRENT SWITCH. Since the positive current is twice the negative current, summing the two currents results in a positive current equal to the negative current when the switch is off. When the positive current source is off, the negative current source will cause the voltage on the FREQUENCY RANGE CAPACITOR to ramp negatively. When the positive current source is on, the voltage will ramp positively at the same rate.

The TRIANGLE BUFFER is a high input impedance, times one amplifier that prevents the following circuitry from loading and thus distorting the ramp waveform. The LEVEL DETECTOR senses when the ramp reaches $\pm$1 volt, generating a signal to switch the current switch. The result is a free running $\pm$ 1 volt triangle wave.

The triangle is fed to the SINE SHAPER which converts it to a $\pm$1 volt sine wave. The SQUARE SHAPER takes a signal from the LEVEL DETECTOR and shapes it into a $\pm$1 volt squarewave. WAVEFORM SELECT routes one of these three waveforms to the AMPLITUDE CONTROL. The AMPLITUDE CONTROL section varies the amplitude of the selected waveform over a range of 1 volt to .316 volts (10 dB). The amplitude is set by a control voltage from the ANALOG CONTROL CHANNELS on the top PCB. The waveform is then routed to the POWER AMPLIFIER. The POWER AMPLIFIER is a timed voltage amplifier that can output up to $\pm$15V at 150 mA. This amplified signal can be further attenuated by the OUTPUT ATTENUATORS giving a total range of 15V to 10mV at the MAIN OUTPUT.

4.2.3.2 TRIGGER CONTROL

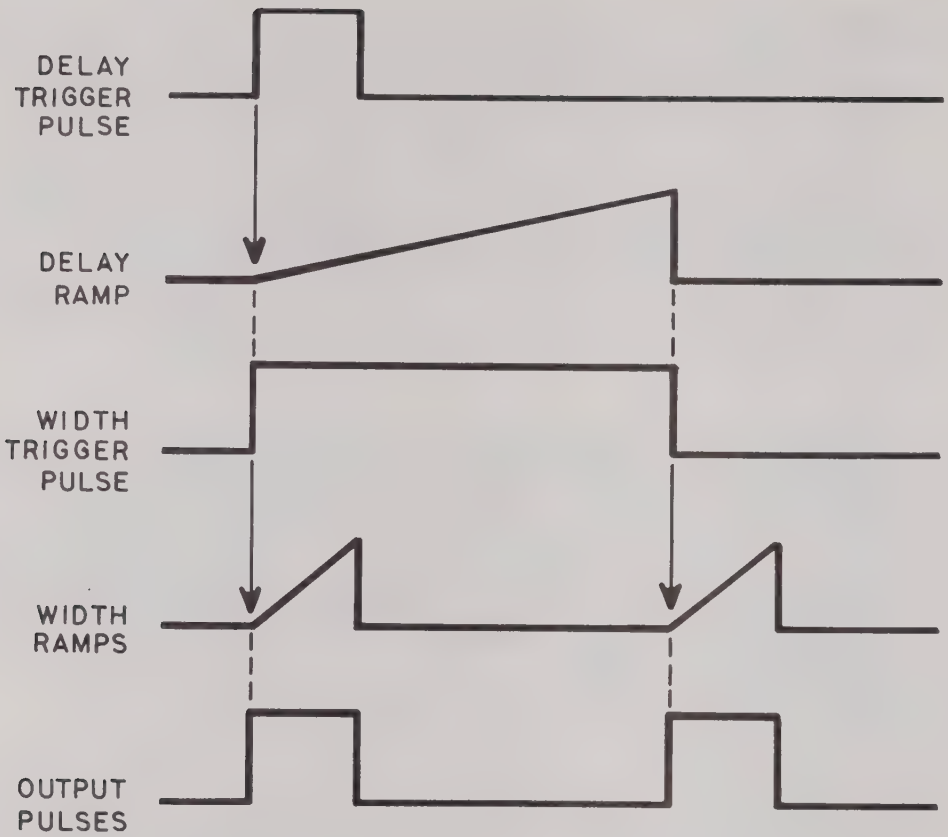
The LOCKOUT AMPLIFIER can stop the triangle from ramping. It senses the triangle at the output of the TRIANGLE BUFFER and when this voltage equals a voltage set by a control signal from the TOP PCB, the LOCKOUT AMPLIFIER pulls current away from the RANGE SELECT CAPACITOR equal to the current changing it. This causes the voltage to hold. This amplifier can be turned on and off by the TRIGGER MODE. If the trigger mode is set to TRIGGER, the LOCKOUT AMPLIFIER is shut off only long enough for the triangle to run through one cycle. In the GATE mode, the triangle is allowed to run as long as the gate signal, from the TRIGGER COMPARATOR, is present. In the RUN mode the LOCKOUT AMPLIFIER is turned off all the time.

The TRIGGER COMPARATOR compares the voltage at the TRIGGER INPUT to a voltage set by the trigger level control. Its two state output switches as the trigger input voltage passes through the trigger level voltage. The resulting two state output is used to turn the LOCKOUT AMPLIFIER on and off. In the counted burst mode, the BURST COUNTER counts the number of cycles the generator runs and at a preset count set by the computer, it generates a signal that enables the LOCKOUT
AMPLIFIER.

4.2.3.3 PULSE GENERATOR

The WIDTH GENERATOR generates a ramp each time it receives a trigger signal from the WIDTH TRIGGER MODE. The duration of the ramp is set by a one of a set of capacitors selected for range control and a current set by a voltage from the ANALOG CONTROL CHANNELS. The duration of the ramp sets the duration of the pulse used for TTL and ECL outputs and goes to the PULSE SHAPER to shape the pulse to have levels of -1 volt and Ø volt for processing through the MAIN OUTPUT.

The DELAY GENERATOR operates the same as the WIDTH GENERATOR. Figure 4.1 shows the timing for the two generators. The delay trigger pulse is selected by the DELAY TRIGGER MODE to be either from the TRIGGER COMPARATOR or the MAIN GENERATOR for either single or multiple pulses respectively. The WIDTH GENERATOR is triggered at either end or both ends of the delay ramp depending on the mode selected, (no delays, delayed or double).



PULSE WIDTH AND DELAY TIMING

FIGURE 4.1

4.3.2 GENERATOR LOOP (CONTINUED)

Q105A and B form a differential amplifier to sense when the triangle has reached ±1V. The triangle is on the base of Q105A and the next peak voltage the triangle is ramping towards it on the base of Q105B. When the triangle voltage reaches this voltage, the transistor pair switches and the voltage at the base of Q105B is set to the other peak voltage by switching the transistor pair Q108 and Q109. When the pair Q109 A and B switches, they switch the pair Q88 and Q90 which routes the positive current source to the current summing function or away from it. All of this circuitry working together generates the triangle.

Q89A and B is the lockout amplifier. The base of Q89A has the lockout level from the TOP PCB. The base of Q89B has the triangle voltage level shifted up to +4.1 to +6.1 volts. This amplifier only works on the negative slope of the triangle. When the triangle voltage is above the lockout level all the current from the positive current source is routed through Q89A to ground. When the triangle voltage has ramped down to the lockout level, half of the current is routed through Q89B to the current summing junction. In this state the sum of the currents on the timing capacitor is zero and the voltage does not ramp. The lockout amplifier is turned off by the transistor pair Q91 and 93. When Q91 is on, all the positive current is routed through it to ground thus disabling the lockout amplifier and allowing the generator to run. The signals that switch Q91 and Q93 are from schematic 6 to be described later.

4.3.3 WAVEFORM SHAPERS

The sine shaper is made up of 6 differential amplifiers with the triangle at one input and the other input grounded. All the amplifiers operate in the same manner but are set to have different active voltage ranges by the emitter resistors. If the active region is set to be between ±.5V, then between these limits the output of the amplifier tracks the triangle voltage, but when the triangle voltage is outside these limits, the amplifier puts out a constant voltage ±.5V. The outputs of all six amplifiers are summed together, approximating a sinewave. The soft turn-on of the base emitter junctions cause considerable rounding of the waveforms which smooths out the breakpoints of the sinewave. The schematic shows the various waveforms throughout the circuit.

The SQUARE SHAPER is composed of a differential switch Q78 and Q79 which is driven from the LEVEL DETECTOR. This switch routes the current from current source Q76 and U59 to R296 or to ground. The result is a ±1V squarewave at R296. Q80 turns off the squarewave when it is not used. The PULSE SHAPER operates the same but receives its inputs from the WIDTH GENERATOR and its output is +1 volt to 0 volts.

Relays K5, K6, K8 and K11 select one of the four waveforms, sine triangle, square or pulse for the main output waveform.

4.3.4 AMPLITUDE CONTROL

U15 is a four quadrant analog multiplier which is used to vary the amplitude over a 10dB range. The waveform from the waveform select relays on schematic 3 if first fed to the times 2 differential amplifier Q39A and Q39B then to the multiplier. The voltage at the base of Q39B can be varied by U13C to balance the waveform about zero volts. U13C receives its input, amplitude balance, from the TOP PCB. The other input to U15 is at pin 18, it is a DC voltage which is multiplied by the waveform.The amplitude is set by this voltage (approximately 2V for maximum amplitude and .6V for -10dB). This signal comes from the TOP PCB and is called AMPLITUDE. It is routed through U13B and U13D. When the INVERT line from the TOP PCB is high, which turns on analog switch U11C, the output of U13D is summed at U13B to invert the output of U13B so it goes from -2V to -.6V instead of +2V to +.6V which inverts the waveform at the output of U15. U14 senses the temperature of U15 and turns Q8 on or off to supply current to a heater in U15 to hold its internal temperature at +55°C.

4.3.4 **AMPLITUDE CONTROL** (CONTINUED)

Q41 and Q45 provide a low impedance for the outputs of U15. The multiplied waveform shows up at the collectors of Q41 on Q45 as 1V peak to peak for maximum amplitude and .3V for -10 dB.These signals drive the bases of Q43A and Q43B to level shift the waveform to drive the POWER AMPLIFIER on schematic 5. The resistance between the emitter at Q45 A and B can be set to 3 values by relays K1 and K3. This is done to further attenuate the waveform by 0dB, -10dB or -20dB. U13A and Q15 and Q16 form 2 current sources to bias this amplifier.

U39A generates a signal to compensate for thermal drift of the amplitude circuitry at low operating frequencies. U39B generates as voltage, from signals from the TOP PCB to control the DC voltage at the output of the POWER AMPLIFIER.

4.3.5 **POWER AMPLIFIER**

The POWER AMPLIFIER is a wide bandwidth operational amplifier operating in the inverting mode U46 forms two cascaded differential amplifiers for the low frequencies. The high frequencies are routed through C134 and C135 to the 2 cascade amplifiers Q55 and Q56, Q81 and Q82. These are buffered by the complimentary emitter follow stage Q58 and Q83 which drives the output stage Q59 and Q84. Feedback to the input is through R305. R316, R318 and R319 form the 50 ohm output impedance for the MAIN OUTPUT. The output voltage can be attenuated by the three 50 ohm 'T' attenuators following the POWER AMPLIFIER. There is a 10dB and two 20dB attenuators that can be used singly or in series to get attenuation from -10dB to -50dB in 10dB steps while always maintaining a 50 ohm output impedance.

K26 and K27 route the output signal to either the front or rear of the instrument. Q114 and Q115 protect the output from a high voltage applied to the output externally. Zener diode, D98 holds the voltage at the collector of Q114 at -18V. If the voltage at the front output exceeds this, D95 will turn on and clamp the output voltage. If the externally applied voltage source can provide more than 500 mA, fuse F8 will blow. Q115 protects against positive voltages in the same manner.

4.3.6 LOCKOUT CONTROL

The outputs of U54B at pins 14 and 15 turn on and off the lockout amplifier on schematic 2. A pulse at U54 pin 12 sets the flip - flop and disables lockout. The positive edge of the squarewave from the level detector at pin 11 resets the flip-flop if pin 10 is low. The pulses to set the flip-flop are generated by U54A and U53C from the trigger signal at U53B. The trigger signals can come from three sources: the pulse generator at U53B pin 10, externally (TRIGGER IN or MANUAL) at U53B pin 11 or from the computer at U53D pin 9. In the RUN mode, U54B pin 10 is held high by the RUN signal at U51A pin 4 preventing the flip-flop from being reset.

In the GATE mode, U54 pin 10 is held low as long as the gate signal is present at U51C pin 14. In the TRIGGER mode, U54B pin 10 is low allowing the flip-flop to be reset after one cycle. In the BURST mode, the flip-flop is prevented from being reset by the signal at U51B pin 7 from the BURST COUNTER.

Trigger signals from TRIGGER INPUT are shaped into a squarewave by Q46 and Q48. Q49 and Q50 provide positive feedback to Q48 to speed up the squarewave and provide noise immunity. U36 stretches the trigger signal so the computer can sense it. Signals from the TRIGGER COMPARATOR are routed to the TRIG LAMP CONTROL circuit. At trigger rates below about 5 Hz, timer U34 is triggered once for each trigger cycle causing the trigger lamp on the front panel to track the trigger signal. At faster trigger rates, the RC network R99 and C49 prevent the trigger signal from retriggering U34 but allows U34 to retrigger itself through U35B. U24 prevents U34 from retriggering itself for 100 mSec after U34 has reset. This causes the trigger lamp to flash at 5 Hz for trigger frequencies above 5 Hz.

U1, U25 and U38 make up the BURST COUNTER. The clock for the counters at U43C pin 8 is either the main generator frequency or the pulse width frequency. The counters are preset to 2049 minus the burst count by the 12 burst count lines from the computer. This number is loaded into the counters by the LOAD signal pulling pin 9 of the counters LOW and LOAD STROBE clocking them. The counters then count up to 2048, this count sets U38 pin 11 high and resets U54B. During auto cal sequences, this counter is used as a prescaler for higher frequencies and its outputs go to the computer as the four lines divided by 2, divided by 16, divided by 256, divided by 2048.

4.3.7 PULSE DELAY

The delay generator is a monostable circuit that generates a pulse each time it receives a trigger. The length of the pulse is determined by the current source, Q11 and U32 and one of the capacitors from the timing set C63. The current source is controlled by the computer by a voltage applied at R158. The capacitor is selected by the computer by turning on the transistor on the upper end of the capacitor. The monostable circuit is composed of Q25, Q26 and Q28. In the stable state Q26 is off, Q25 is on and Q28 is on and the voltage at the base of Q25 is held at -10V. The trigger pulse comes from Q23. This turns Q25 off. With Q25 off the voltage at the base of Q28 goes up to -7V which turns off Q28 and holds Q26 on when the trigger pulse goes away after 10 nSec. Now, the current source starts changing the selected capacitor positively. When the voltage on the capacitor reaches -7V, Q25 turns on and Q26 turns off. The voltage on the base at Q28 goes down to -11V which pulls the voltage on the cap down to -10 volts. This is back to the stable state again. The pulse at R131 is the output of the circuit. The width of the pulse can be varied from 18 nSec to 20 mSec.

The signal that triggers the delay generator can come from the main generator or from an external trigger. Trigger signals from the main generator are level shifted by Q18 and Q19 and routed to U3B pin 9. External triggers are at U26B pin 9. Which signal is used is selected by the state of PULSE TRIG, from the computer at U26 pin 11 and pin 12. When no pulses are desired, neither are selected by PULSE ENABLE at U26 pin 10 and U3 pin 10. The selected trigger signal is shaped into a 10nSec pulse by U28A and U28D and routed through U4 to Q23 and Q24 which generate the pulse that triggers the DELAY GENERATOR.

SYNC OUT is switched from being coincident with the triangle to being coincident with the delay pulse in the pulse mode. The selection is performed by U5A and U5B and then level shifted to TTL levels by Q5 and Q6. It is then routed through U9C and U10C to U10B where it can be shut off by SYNC OFF. It is finally routed to the 50 ohm driver U8B and through protection fuse F5 to the SYNC OUT BNC.

In the burst mode, internal triggering of the main generator is handled by the computer for low rates (see Section 4.3.6) at fast rates (greater than 500 Hz). The DELAY and WIDTH (see Section 4.3.8) GENERATORS are used to trigger it. This is done by putting them in a mode where the end of the delay triggers the width and the end of the width triggers the delay. This gives a free running waveform that is routed to U53B on schematic to trigger the main generator. This mode is selected by enabling HF BURST ENABLE at U4B pin 10.

4.3.7 **PULSE DELAY** (CONTINUED)

The BURST/SWEEP SYNC SELECTOR is set to output pulses from the delay generator in this mode at U9B pin 5. The lower frequency burst/sweep syncs are at U9A pin 2 and the actual output is at U9D pin 13 and is protected by fuse F3.

4.3.8 **PULSE WIDTH**

The PULSE WIDTH generator is identical to the pulse delay generator on Schematic 7. The pulses from the width generator at R139 are routed to U4 pin 13. Pulses longer than 20mSec are generated by the computer and appear at U4C pin 12. Normal or inverted ECL pulses are selected at U3C pin 12 or 13, and routed through U5D and U5C. They are then level shifted to standard ECL levels by D1, sent through U6A and U6B to the protection fuse F1 and to the ECL OUTPUT. The outputs of U4C also are sent to schematic 3 to generate pulses for the MAIN OUTPUT and to Q1 and Q3 to generate the TTL OUTPUT. Q1 and Q3 level shift the pulses to TTL levels. Then U31 selects normal or inverted pulses and U8 drives the TTL OUTPUT through protection fuse F4.

The WIDTH GENERATOR can be triggered at either end of the delay pulse (see Figure 4.1). These 2 trigger pulses are shaped by U29A and B or U30B and C and selected by NO DELAYand DELAYED from the computer. DELAYS longer than 20mSec are generated by the computer and are at U29C pin 12. Short delays, from the DELAY GENERATOR are at U29 pin 13.

Delay pulses are level shifted by Q20 and Q21 to be sent to the computer at DELAY CAL for calibration. The WIDTH pulse at Q1 is sent to the computer at WIDTH CAL for calibration.

4.3.9 **CENTRAL PROCESSING UNIT, CPU**

This schematic contains the computer circuits which make up the CPU which controls the instrument. A 6502 microprocessor is used, U60. It generates signals on 3 busses for reading and writing to the other circuits in the CPU. They are the data, address and control busses. Extra control bus signals are generated by gates to operate some of the I/O ports.

A 1 MHz crystal oscillator circuit Y1 and U59, generates a clock signal which runs the microprocessor.

4.3.9 **CENTRAL PROCESSING UNIT, CPU** (CONTINUED)

A power on reset is provided by timer U65 to start things off.

U47 decodes the address bus to select the different memory devices. U41 thru U44 are 2764 EPROM's (8K bytes each) which contain the computer program. U48-51 make up 2K bytes of RAM for temporary storage. U45 is 2K bytes of EPROM for non-volatile storage. The EEPROM write pulse is generated by one-shot timer U61.

U54, 46 and 34 further decode the address bus to select the I/O ports. Note that for U18-U27, this schematic shows only the computer interface to these IC's. The I/O lines of these IC's are shown on other schematics.

U44 is the GPIB controller addressed as an I/O port. U38 and U39 are tranceivers for the GPIB data and control lines which provide the proper electrical interface to the GPIB bus.

4.3.10 **FRONT PANEL AND INTERFACE**

This schematic shows the front panel pushbutton switches, the LED displays and the interface circuitry for them. U37 is a combination keyboard/display controller IC. The switches operate as a multiplexed array. U33 generates 8 strobe lines. When a switch is pushed it connects a strobe line to one of the return lines RL0-RL7 on U37. An interrupt is generated by U37 to indicate a change in switch status.

The LED's are also driven in a multiplexed mode. U30, 31 and 32 generate 16 digit strobe lines to drive the LED cathodes (5 are not used). U35 and 36 and Q3-10 drive the LED anodes (digit segments). Capacitors C46-64 slow down the transient times of the drive signals to prevent interference with other circuits.

THE MAN TRIGGER switch and the TRIG LED connect to the bottom board via the top board.

4.3.11 **ANALOG CONTROL**

This schematic shows the circuits which make the analog control signals for the instrument.

There are 2, 12 bit DAC's. The DAC's operate in a current mode, both the ref input and the output.

4.3.11 **ANALOG CONTROL** (CONTINUED)

The sample/hold DAC (U13) output current is converted to a voltage from Ø to 4V at TP3 by amplifier U12B. This voltage is distributed by multiplexer U6 and 7 to the 11 sample/hold circuits of U1-3. This scheme creates 11 separate DC voltages for use to control analog circuits in the instrument.

The sample/hold circuits are refreshed every 65 milliseconds under control of the microprocessor. For each circuit, the correct voltage is output at TP2. Then the appropriate multiplexer channel is opened for a period of time, then closed. The voltage is stored on the hold capacitor C11-21 until the next refresh. Refreshing all 11 channels takes 6 milliseconds.

The frequency control has its own DAC, U14, to allow for rapid frequency changes during sweep. Its digital number is always twice the number on the frequency display. The frequency control is calibrated by two of the analog control voltages. The gain correction voltage makes a current which is summed into the reference current input of the DAC through R37. The offset correction voltage is inverted by U12C and made into a current by R38 which is summed with the DAC output corrent at the summing junction of U12D. A third current is summed from U1ØC which is derived from the voltage at the VCF input. U11A and B are analog switches used to enable or disable the VCF input.

Amplifier U12D sums the three currents and with FET Q2 makes the frequency control current which goes to the current sources of the main generator on the bottom board. Also a voltage proportional to that current is made by U1ØA which drives the V:F output.

On the 2Ø MHz range U11C switches on the frequency linearizing circuit of U1ØB. This circuit adds current to Q2 at the high end of the frequency range to compensate for delays in the main generatror loop, thus improving the linearity of the highest speed range.

4.3.11 **ANALOG CONTROL** (CONTINUED)

The amplifiers of U4 make up a peak detector to measure the waveform amplitude for calibration. The waveform enters the circuit at J6 at one-third the amplitude of the output waveform (unloaded). Either the straight or inverted waveform is switched to U4A by analog switch U5A or U5B. Thus either the positive or negative waveform peak is detected by the circuit of U4C and U4D. D1 rectifies the signal and stores the peak to the comparator circuit U8. The output of the comparator is read by an I/O port.

The microprocessor performs a routine which measures the voltage at the comparator output to determine the correct voltage.

4.3.12 **DIGITAL I/O**

This schematic shows the digital signal lines from I/O ports which control various circuits on the bottom board and some other circuits.

One of the I/O lines becomes the frequency greater than marker signal. It has a fuse protecting it from excessive voltage applied to it. See Fuses (4.4).

The frequency calibration circuit is able to measure the frequency or period of the main generator, the symmetry and the pulse width and delay.

Multiplexer U15 selects one of the divisions of the main generator frequency which come from the burst counter on the bottom board or the pulse width or delay.

The circuit can operate either as a frequency counter or a timer of the waveform period. U25 contains two counter/timers which are used. One timer operates free running and generates a squarewave at Port B, bit 7 (pin 17). The other is used as a counter and counts pulses at Port B, bit 6 (pin 16).

In the frequency counter mode, the selected signal at U15 pin 5 becomes the input frequency at U16 pin 9. The timer generates a slower squarewave which may be divided further by U17 and is routed by the gates to U16 pin 10. This signal becomes the gating signal to the frequency counter at U25 pin 16. The microprocessoor knows when the gate opens and closes by looking at U25 pin 15. It therefore can determine the count for one entire gate time and from that the frequency.

4.3.12 **DIGITAL I/O** (CONTINUED)

In the timer mode the circuit measures the time that the gate is opened by the signal at U15 pin 5 which becomes the timer enable signal at U16 pin 9. A faster squarewave is generated at U25 pin 17 which becomes the input frequency which is counted at U25 pin 16. The timer enable signal is monitored by the microprocessor at U27 pin 9 so it knows again when the gate opens and closes. The period of the measured signal is determined from the count for one gate time.

A four position DIP switch S1 is mounted on the back side of the top PCB so as to be accessible from the top. It is used to program different options of the instrument's operation.

The schematic also shows the power supplies coming onto the board and their filter caps. Note that the analog (A) and digital (D) grounds are separate on the top PCB.

4.4 FUSES

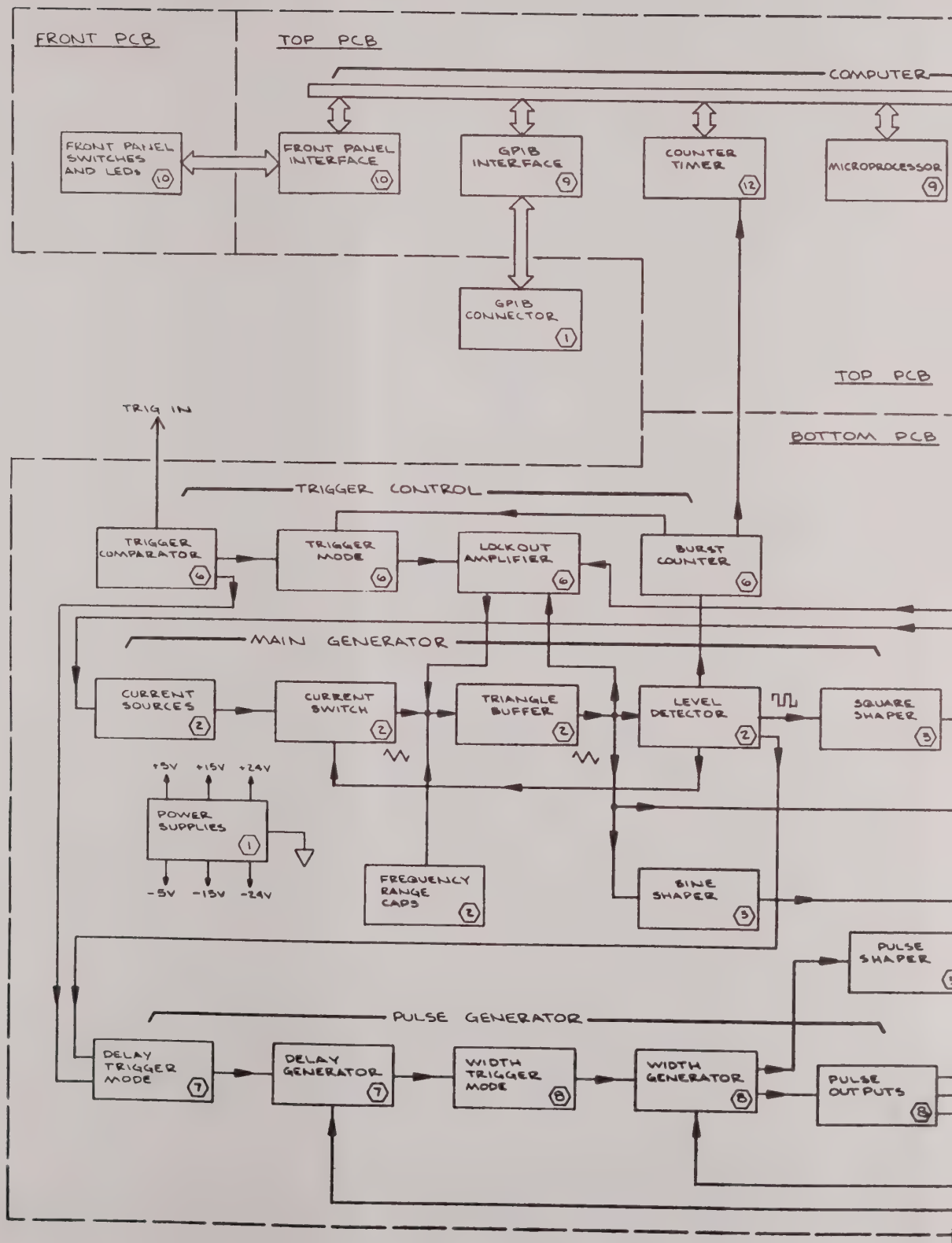
The Model 628 contains several fuses besides the main power input fuse (2.2.1). These are to protect the power supply and the output signals which connect to external BNC jacks. If one of the outputs is not operating the appropriate fuse should be checked. The fuse may be found from the component locator drawing of the boards. The internal fuses are listed:

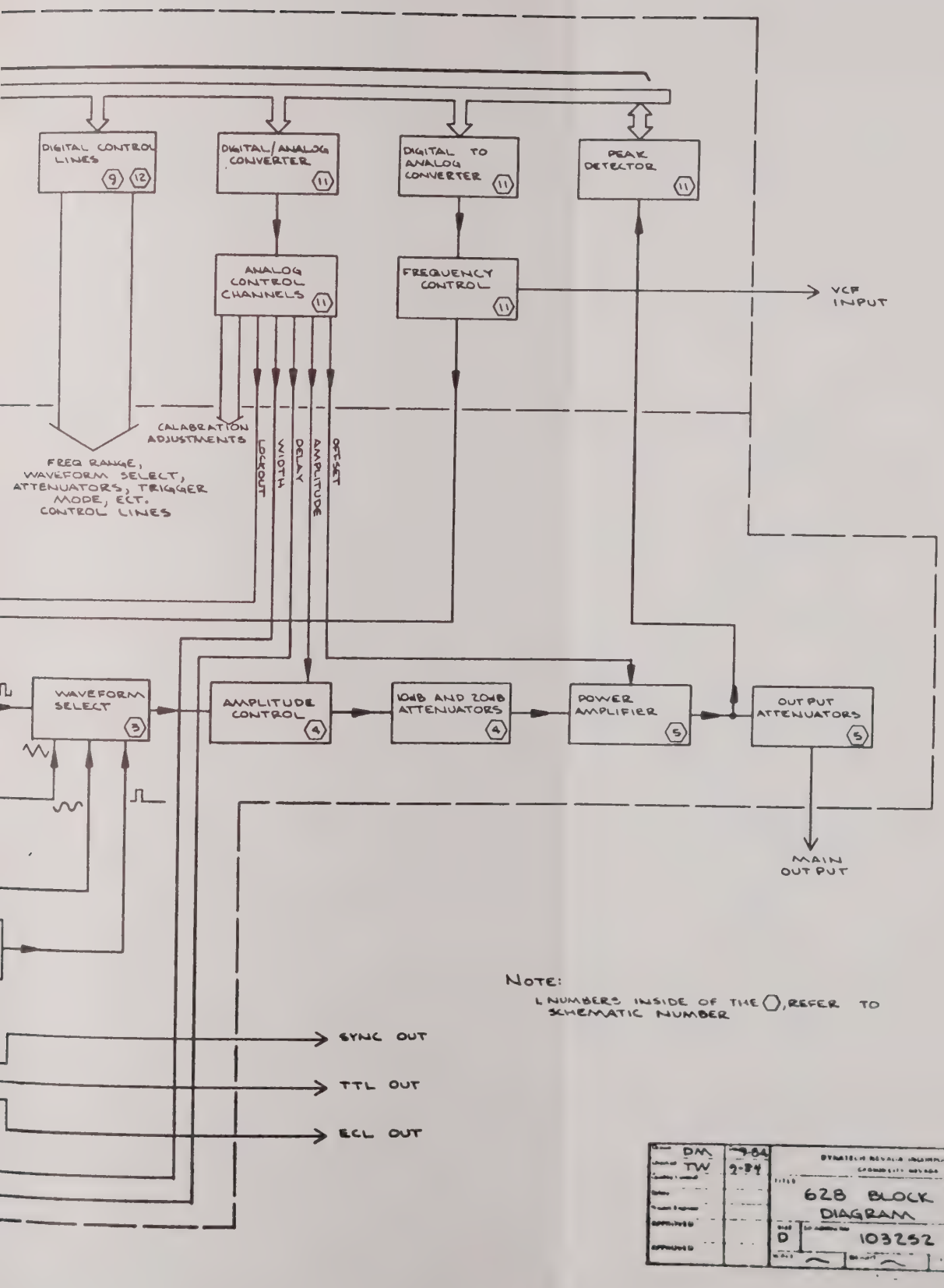
DESCRIPTION	PCB	REF DES	AMPS
+5V Supply	Bottom	F6	6.25
Front Main Out	Bottom	F8	1/2
Rear Main Out	Bottom	F7	1/2
Sync Out	Bottom	F5	1/16
Burst/Sweep Sync	Bottom	F3	1/16
ECL Pulse	Bottom	F1	1/16
TTL Pulse	Bottom	F4	1/16
Freq >Marker	Top	F1	1/16

Notes: F6 is a 3AG slo-blo fuse. Others are subminiature fuses, Littlefuse PICO-II Fast Acting, type 255. See the parts list for the part number if ordering from Exact Electronics/Dynatech Nevada, Inc.

SECTION 5

SCHEMATICS AND COMPONENT LOCATIONS

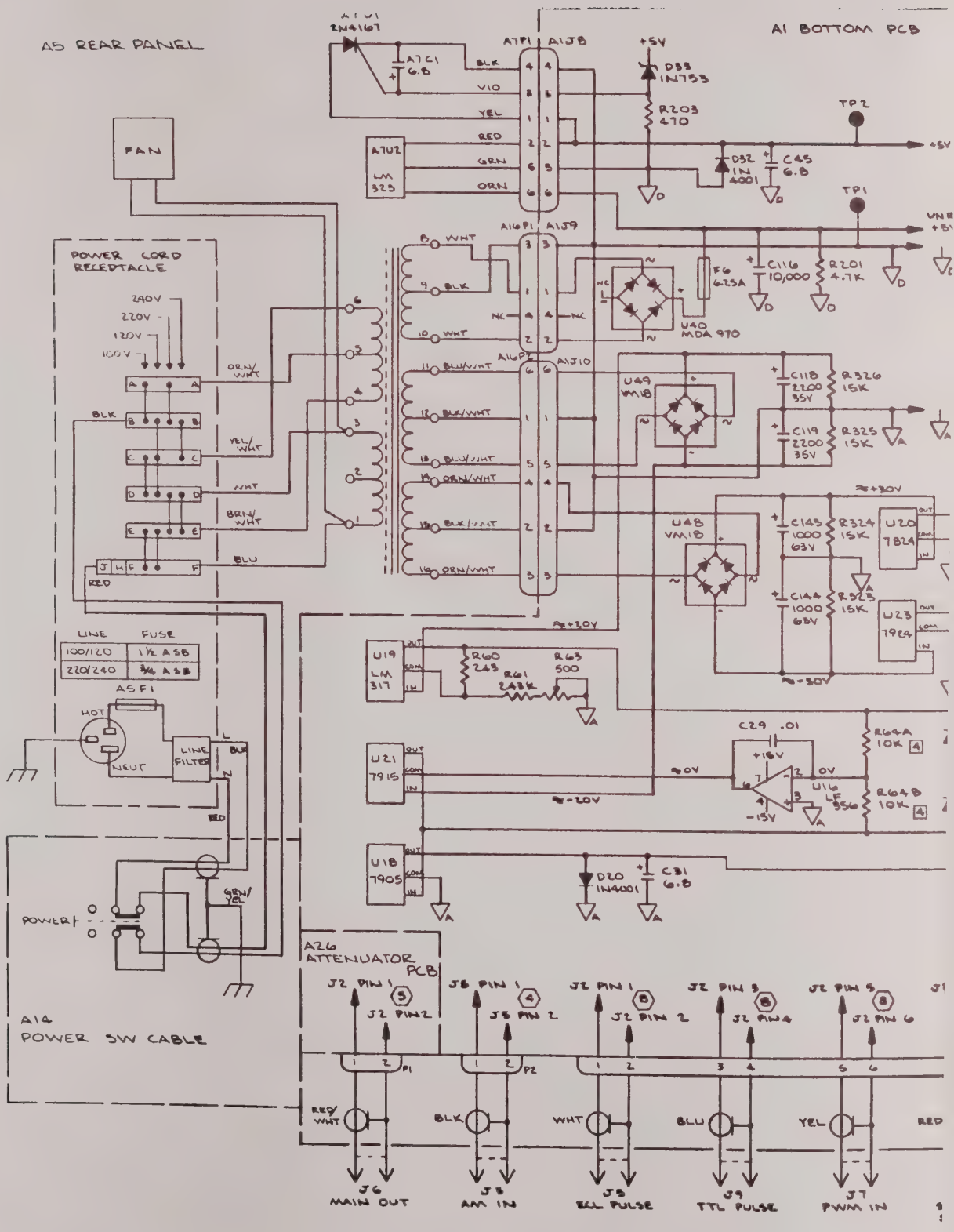

FRONT PCB
TOP PCB
COMPUTER
FRONT PANEL SWITCHES AND LEDs (10)
FRONT PANEL INTERFACE (10)
GPIB INTERFACE (9)
COUNTER TIMER (12)
MICROPROCESSOR (9)
GPIB CONNECTOR (1)
TOP PCB
BOTTOM PCB
TRIG IN
TRIGGER CONTROL
TRIGGER COMPARATOR (6)
TRIGGER MODE (6)
LOCKOUT AMPLIFIER (6)
BURST COUNTER (6)
MAIN GENERATOR
CURRENT SOURCES (2)
CURRENT SWITCH (2)
TRIANGLE BUFFER (2)
LEVEL DETECTOR (2)
SQUARE SHAPER (3)
+5V +15V +24V
POWER SUPPLIES (1)
-5V -15V -24V
FREQUENCY RANGE CAPS (2)
SINE SHAPER (3)
PULSE SHAPER
PULSE GENERATOR
DELAY TRIGGER MODE (7)
DELAY GENERATOR (7)
WIDTH TRIGGER MODE (8)
WIDTH GENERATOR (8)
PULSE OUTPUTS (8)

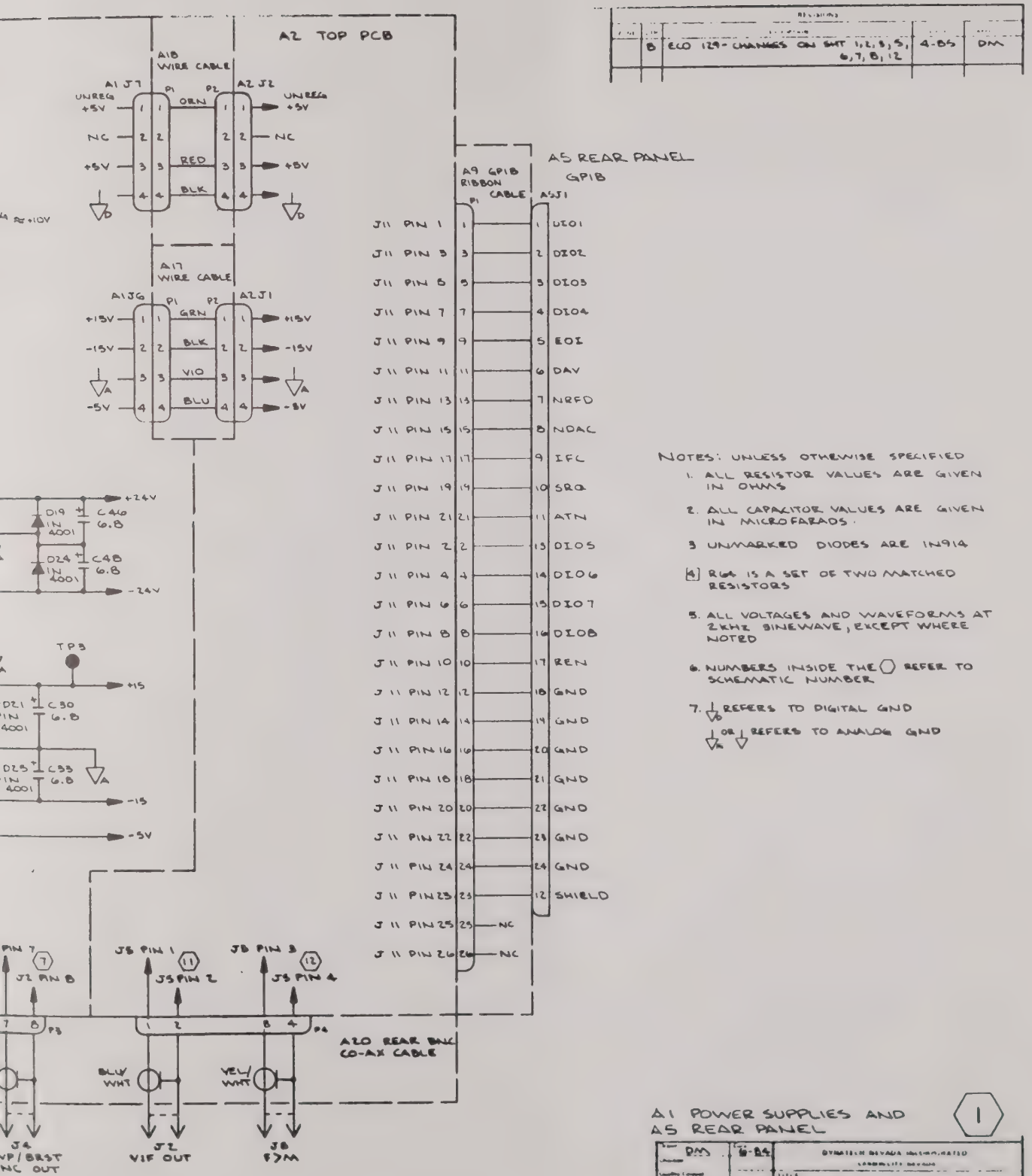


NOTE:

1. NUMBERS INSIDE OF THE ⬡, REFER TO SCHEMATIC NUMBER

DM	7-84	DYNATRONIX RESEARCH INCORPORATED
TW	2-84	628 BLOCK DIAGRAM
		SIZE D — 103252 — B


A5 REAR PANEL
A1 BOTTOM PCB
A1 U1
2N4167
A7C1
6.8
A7P1
A1J8
+5V
D33
IN753
R203
470
TP2
+5V
A7U2
LM
323
BLK
VIO
YEL
RED
GRN
ORN
D32
IN
4001
C45
6.8
TP1
FAN
POWER CORD
RECEPTACLE
240V
220V
120V
100V
A1P1
A1J9
WHT
BLK
WHT
NC
F6
6.25A
C116
10,000
R201
4.7K
U40
MDA 970
A1P2
A1J10
BLU/WHT
BLK/WHT
BLU/WHT
ORN/WHT
BLK/WHT
ORN/WHT
U49
VM18
C118
2200
35V
R326
15K
C119
2200
35V
R325
15K
ORN/
WHT
YEL/
WHT
WHT
BRN/
WHT
BLU
BLK
RED
U48
VM18
≈+30V
C143
1000
63V
R324
15K
U20
7824
C144
1000
63V
R323
15K
U23
7924
≈-30V
LINE
FUSE
100/120
1½ ASB
220/240
¾ ASB
ASF1
HOT
NEUT
LINE
FILTER
U19
LM
317
R60
243
R61
243K
R63
500
C29
.01
+16V
0V
-15V
U16
LF
356
R64A
10K
R64B
10K
U21
7915
≈0V
≈-20V
U18
7905
D20
IN4001
C31
6.8
POWER
A14
POWER SW CABLE
A26
ATTENUATOR
PCB
J2 PIN 1
J2 PIN 2
J6 PIN 1
J6 PIN 2
J2 PIN 1
J2 PIN 2
J2 PIN 3
J2 PIN 4
J2 PIN 5
J2 PIN 6
P1
P2
RED/
WHT
BLK
WHT
BLU
YEL
RED
J6
MAIN OUT
J8
AM IN
J5
ECL PULSE
J9
TTL PULSE
J7
PWM IN



	B	ECO 129 - CHANGES ON SHT 1, 2, 3, 5, 6, 7, 8, 12	4-85	DM

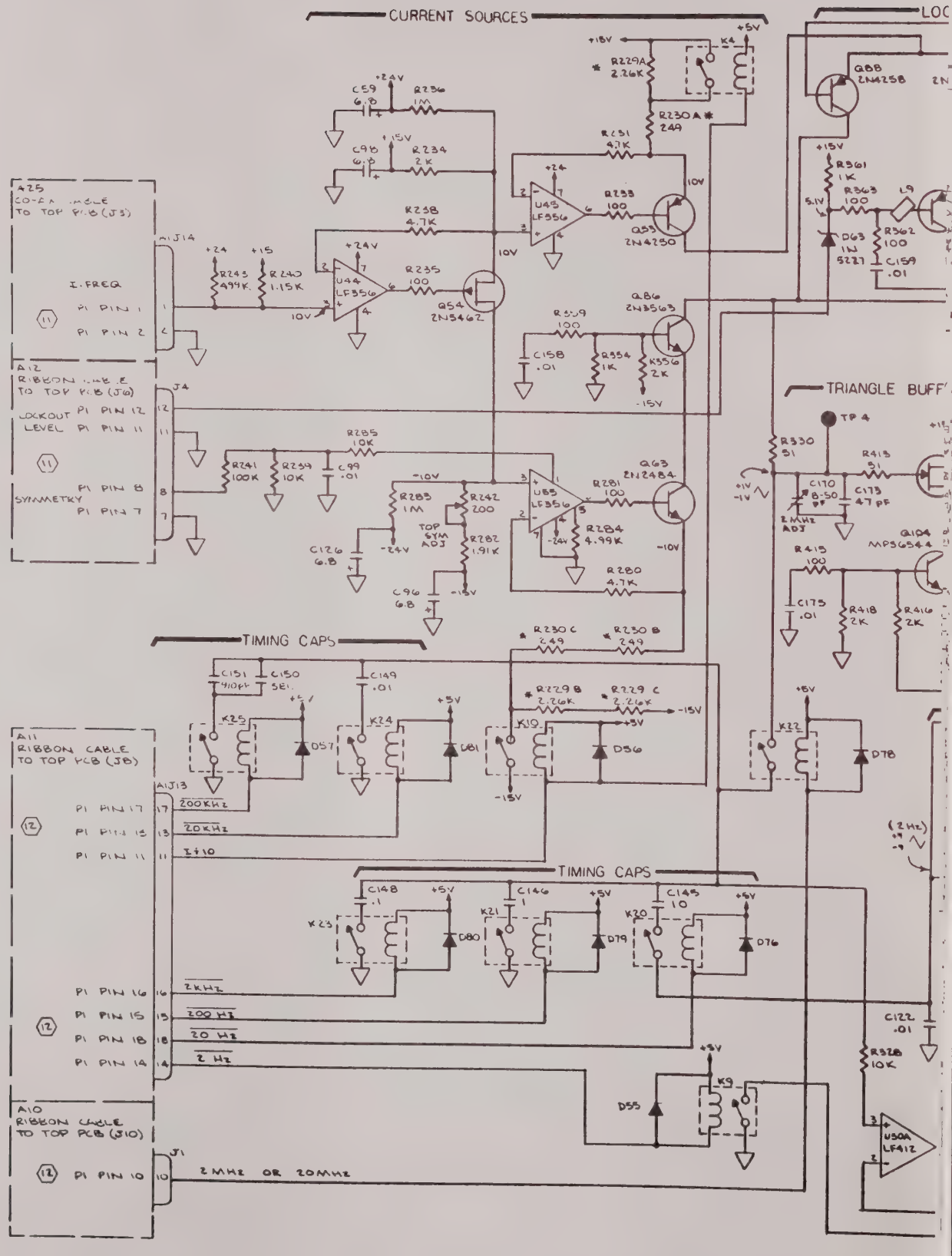
NOTES: UNLESS OTHERWISE SPECIFIED

1. ALL RESISTOR VALUES ARE GIVEN IN OHMS
2. ALL CAPACITOR VALUES ARE GIVEN IN MICROFARADS.
3. UNMARKED DIODES ARE 1N914
4. R6A IS A SET OF TWO MATCHED RESISTORS
5. ALL VOLTAGES AND WAVEFORMS AT 2KHZ SINEWAVE, EXCEPT WHERE NOTED
6. NUMBERS INSIDE THE ⬡ REFER TO SCHEMATIC NUMBER
7. ⏚ REFERS TO DIGITAL GND
   ⏚ OR ⏚ REFERS TO ANALOG GND

A1 POWER SUPPLIES AND
A5 REAR PANEL

(1)

DM	6-84	DYMATRON NEVADA INCORPORATED
		TITLE: 628 SCHEMATICS
		SIZE D — 103253 — REV B
		SHEET 1 OF 12


CURRENT SOURCES
TRIANGLE BUFF
TIMING CAPS
TIMING CAPS
A25
CO-AXIAL CABLE
TO TOP PCB (J3)
I. FREQ
PI PIN 1
PI PIN 2
A12
RIBBON CABLE
TO TOP PCB (J6)
LOCKOUT LEVEL
PI PIN 12
PI PIN 11
SYMMETRY
PI PIN 8
PI PIN 7
A11
RIBBON CABLE
TO TOP PCB (J8)
PI PIN 17
PI PIN 15
PI PIN 11
PI PIN 16
PI PIN 15
PI PIN 18
PI PIN 14
A10
RIBBON CABLE
TO TOP PCB (J10)
PI PIN 10
2MHz OR 20MHz
200KHz
20KHz
2KHz
200 Hz
20 Hz
2 Hz
TOP SYM ADJ
2MHz ADJ
U45 LF356
U44 LF356
U43 LF356
U85 LF356
U50A LF412
Q54 2N5462
Q55 2N4250
Q86 2N3563
Q63 2N2484
Q88 2N4258
Q104 MPS6544
D57
D81
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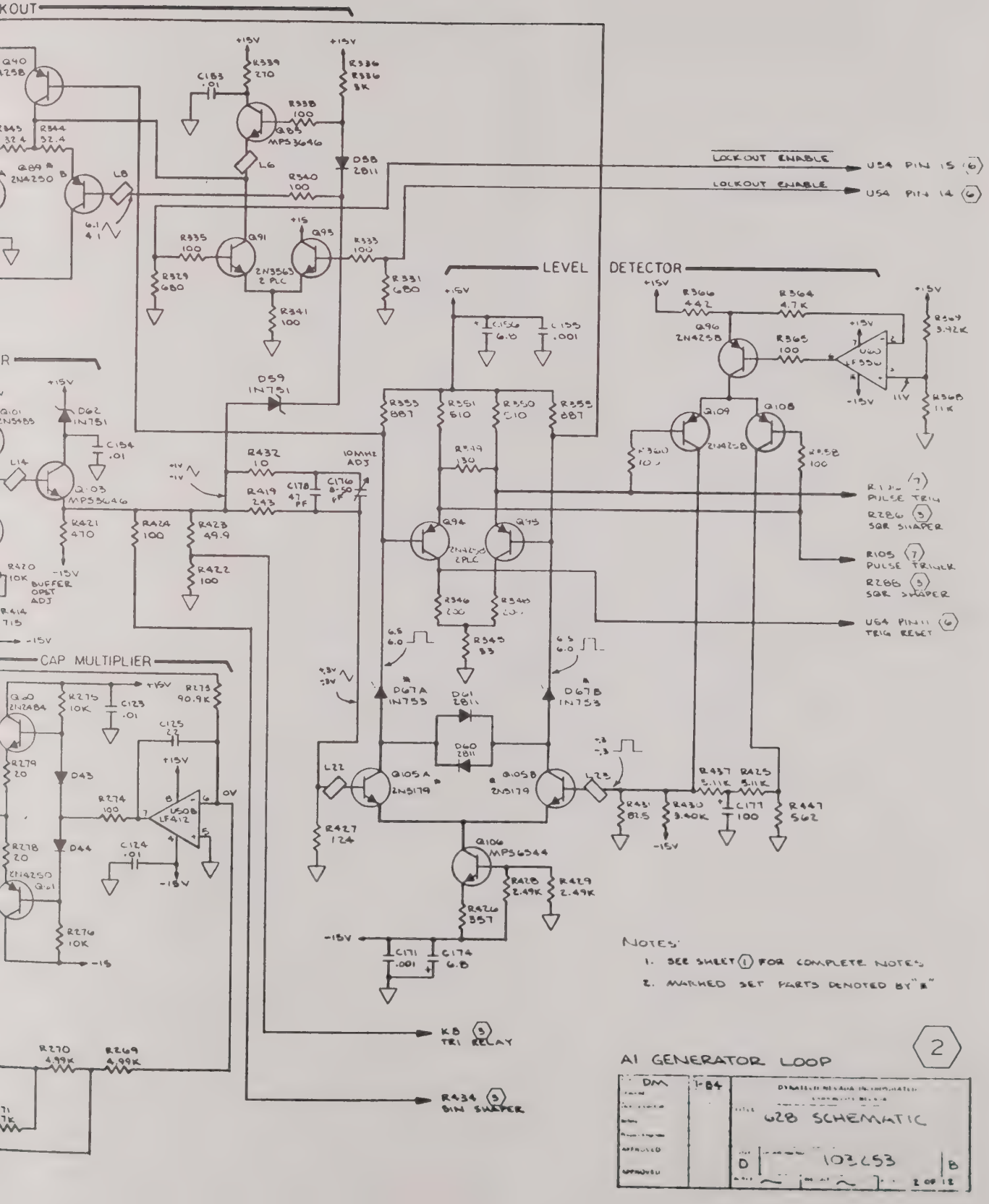
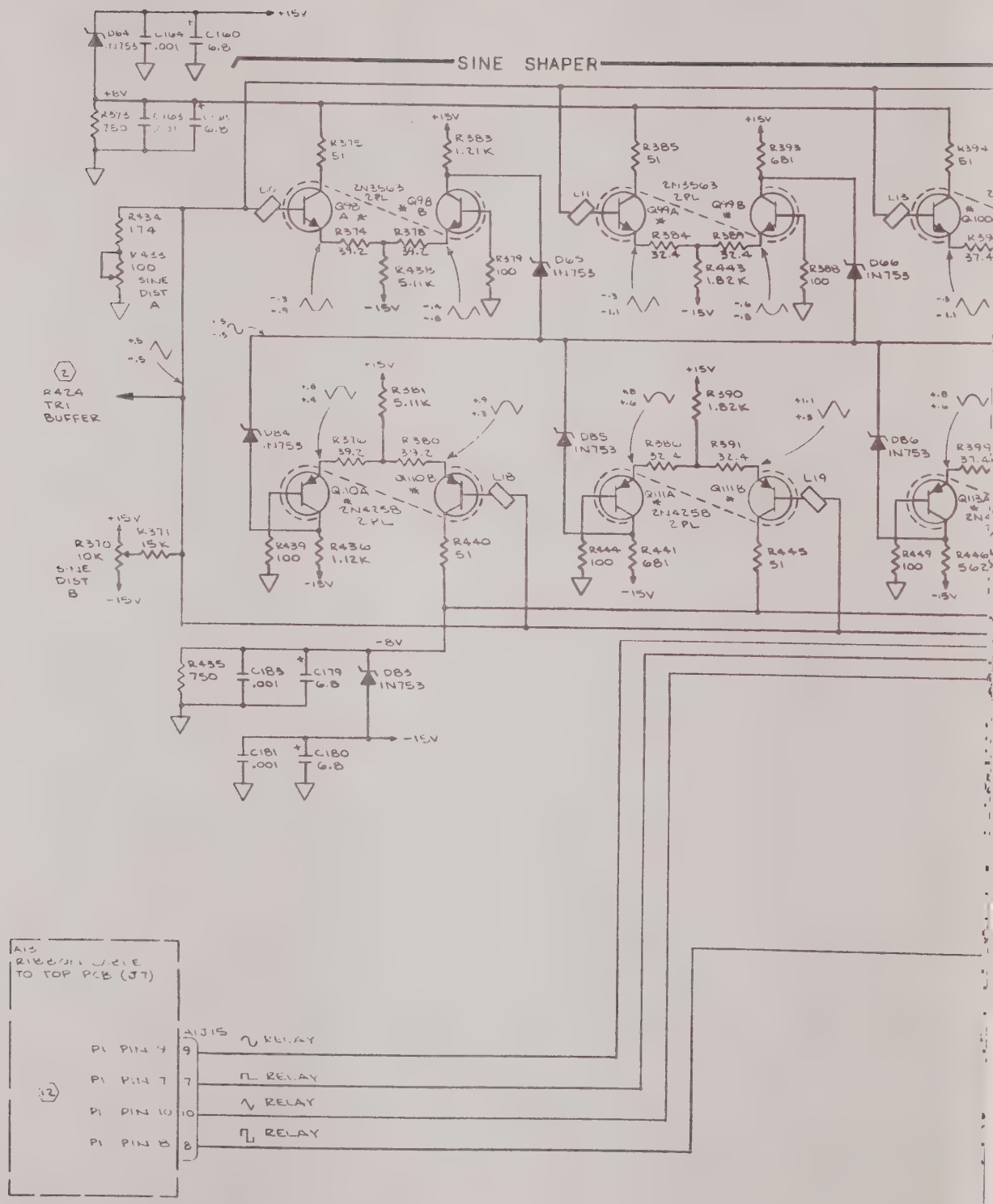
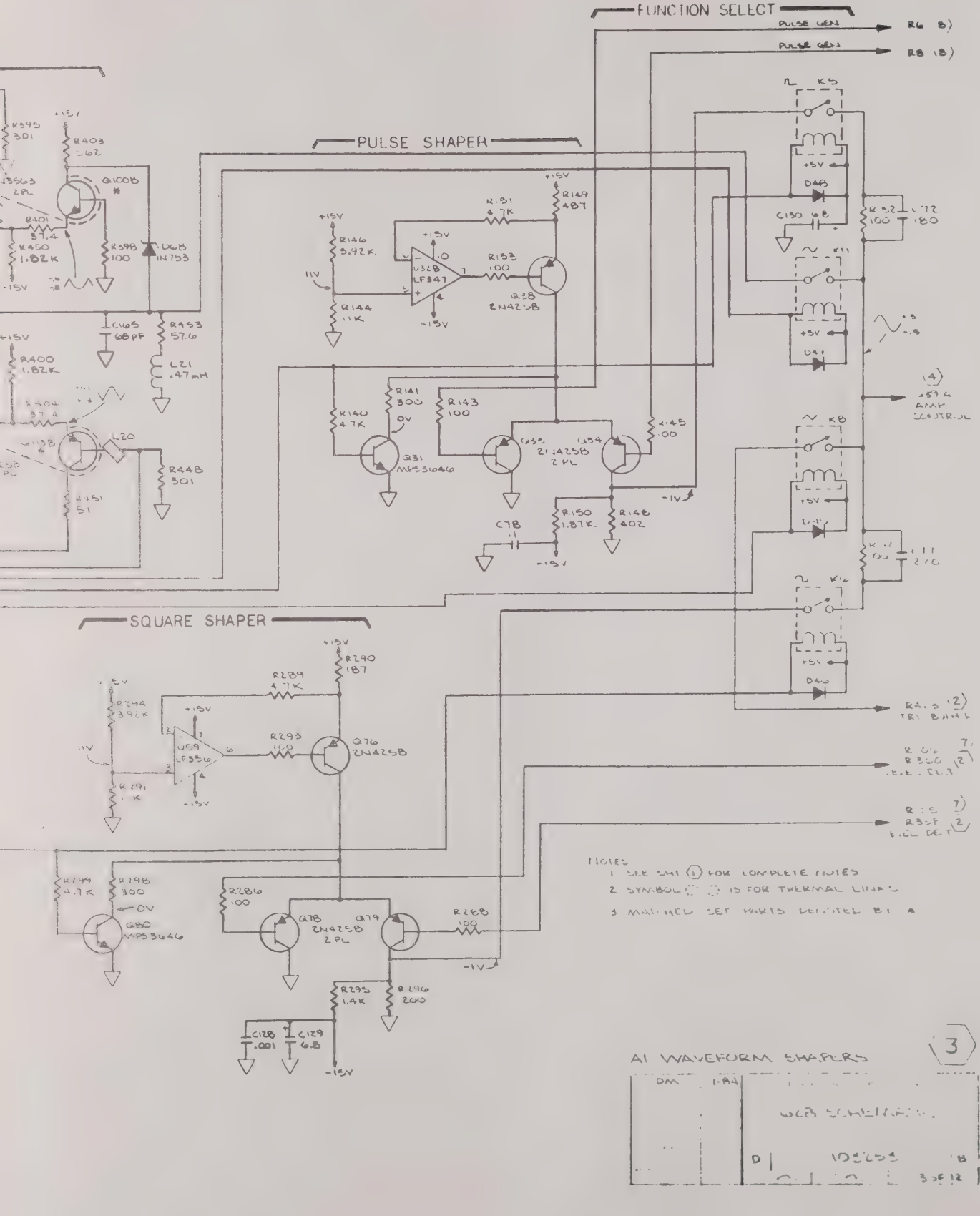
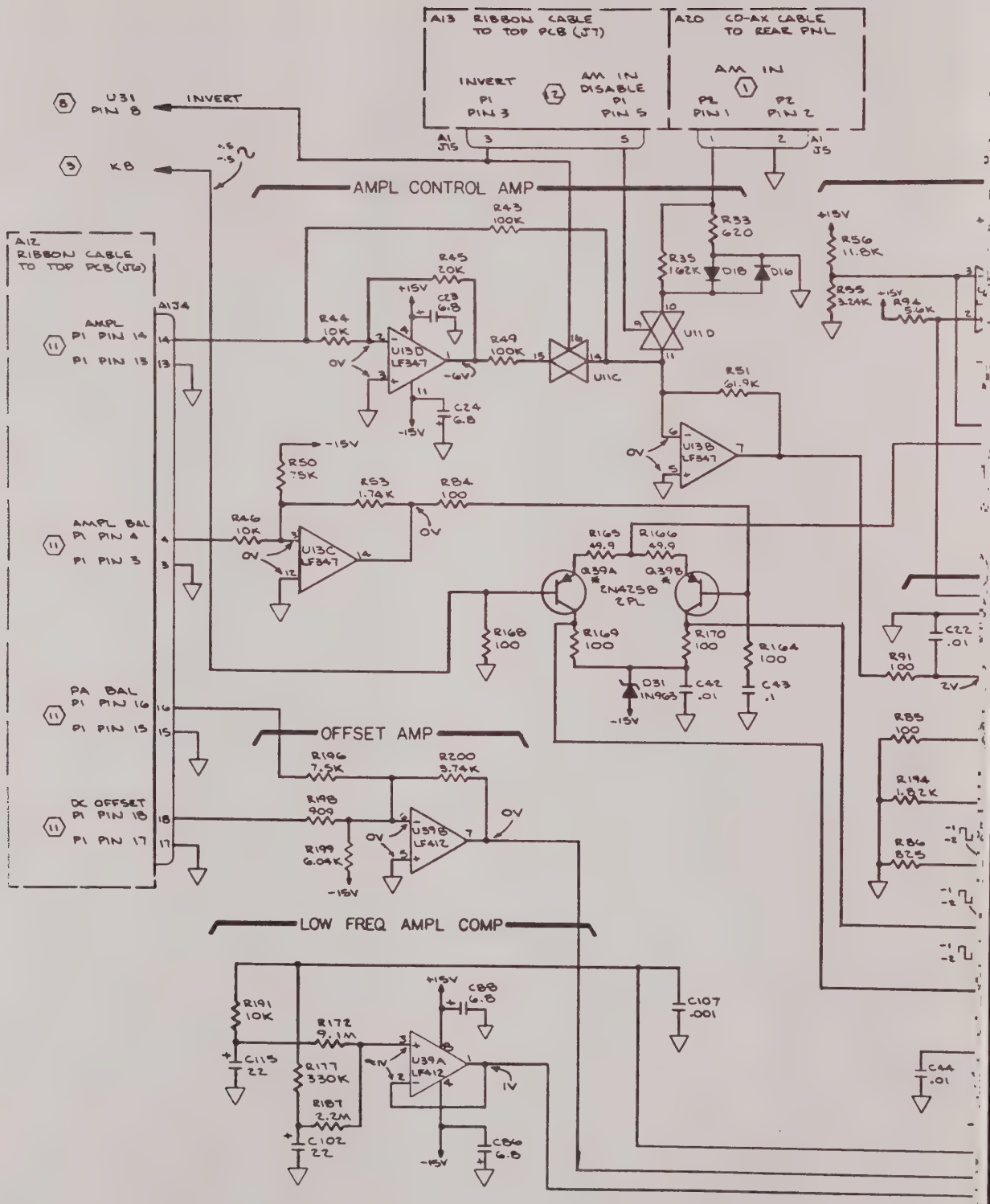
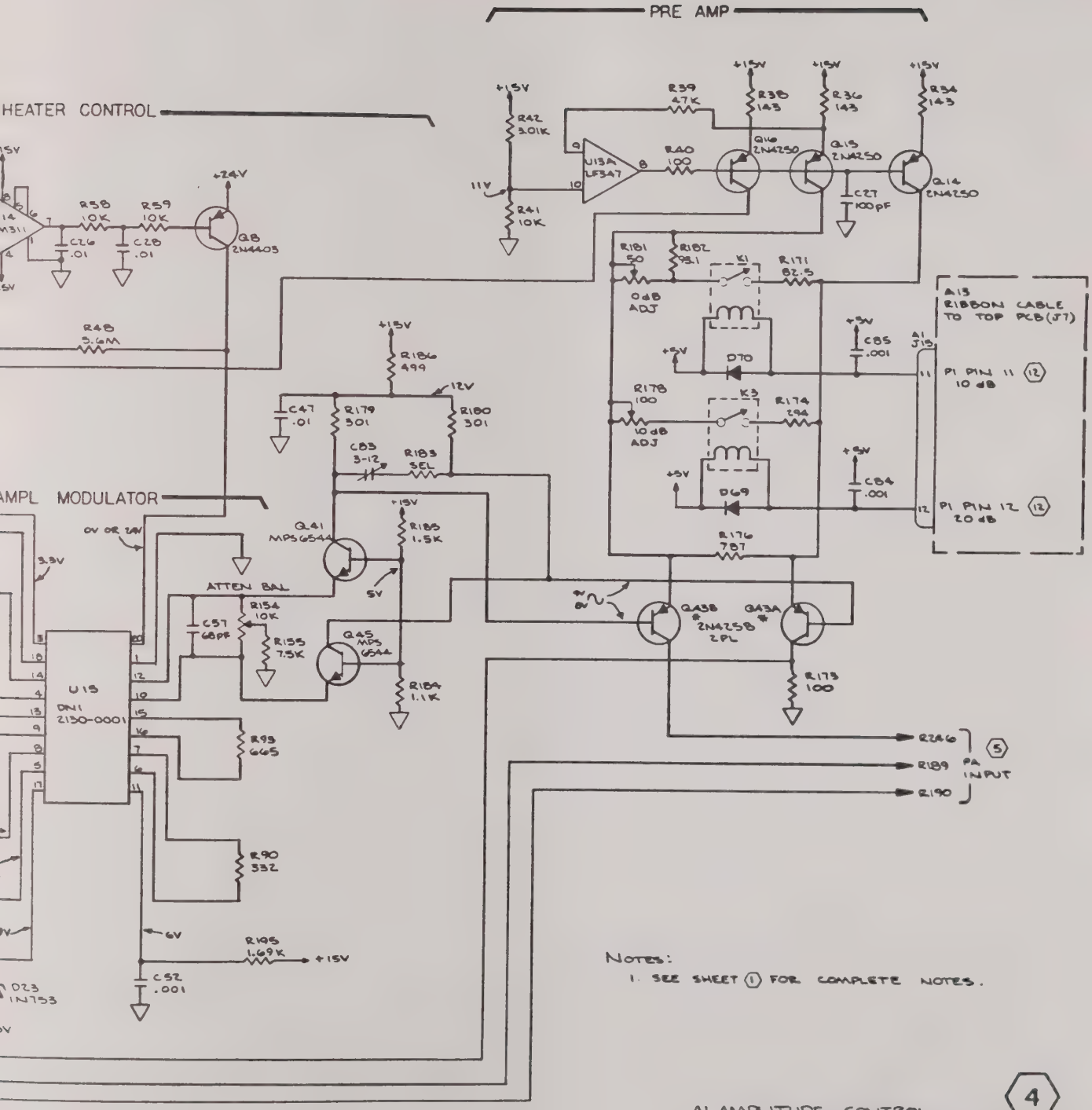
K21
K20
K9
K4


LOCKOUT
LEVEL DETECTOR
CAP MULTIPLIER
LOCKOUT ENABLE
U54 PIN 15 (6)
LOCKOUT ENABLE
U54 PIN 14 (6)
U54 PIN 11 TRIG RESET (6)
KB TRI RELAY (5)
R434 DIN SWEEPER (5)
R105 (7) PULSE TRIG
R286 (5) SQR SHAPER
R105 (7) PULSE TRIG
R286 (5) SQR SHAPER
BUFFER OFST ADJ
10MHz ADJ
NOTES:
1. SEE SHEET (1) FOR COMPLETE NOTES
2. MARKED SET PARTS DENOTED BY "*"
A1 GENERATOR LOOP
(2)
628 SCHEMATIC
103-0153
DM
1-84


SINE SHAPER
+15V
-15V
+8V
-8V
D64 IN753
C164 .001
C160 6.8
R373 750
R384 174
R433 100 SINE DIST A
R370 10K SINE DIST B
R371 15K
R372 51
R374 39.2
R378 39.2
R379 100
R435 5.11K
D65 IN753
Q98 A
Q98 B
2N3563 2PL
R385 51
R393 681
R384 32.4
R388 32.4
R443 1.82K
R388 100
D66 IN755
R394 51
R424 TRI BUFFER
R381 5.11K
R376 39.2
R380 39.2
D64 IN753
Q110A
Q110B
2N4258 2PL
R439 100
R436 1.12K
R440 51
R390 1.82K
R386 32.4
R391 32.4
D65 IN753
Q111A
Q111B
R444 100
R441 681
R445 51
D66 IN753
R435 750
C183 .001
C179 6.8
D63 IN753
C181 .001
C180 6.8
A15 RIBBON CABLE TO TOP PCB (J7)
J15
P1 PIN 9
P1 PIN 7
P1 PIN 10
P1 PIN 8
RELAY
RELAY
RELAY
RELAY


FUNCTION SELECT
PULSE GEN
PULSE GEN
PULSE SHAPER
SQUARE SHAPER
+15V
-15V
+5V
11V
0V
-1V
R403 562
R401 37.4
R450 1.82K
R398 100
D68 IN753
R400 1.82K
R404 37.4
R451 51
C165 68PF
R453 57.6
L21 .47mH
L20
R448 301
R146 5.92K
R144 11K
R151 4.7K
R149 487
R153 100
Q28 2N4258
U32B LF347
R141 300
R140 4.7K
R143 100
Q31 MPS3646
Q33 2N4258 2PL
Q34
R145 100
R150 1.87K
R148 402
C78 .1
R289 4.7K
R290 187
R292 3.92K
R293 100
Q76 2N4258
U59 LF356
R291 1K
R299 4.7K
R298 300
Q80 MPS3646
R286 100
Q78 2N4258 2PL
Q79
R288 100
R295 1.4K
R296 200
C128 .001
C129 6.8
K5
K11
K8
K16
D40
D41
C130 68
R432 100
L72 180
C111 220
(4) +5V & AMP. CONTR. SL
R4.3 (2) TRI BLANK
NOTES
1 SEE SH1 (1) FOR COMPLETE NOTES
2 SYMBOL ⬡ IS FOR THERMAL LINKS
3 MARKED SET MARKS DEFINED BY A
A1 WAVEFORM SHAPERS
(3)
DM
1-84
D
3 OF 12


A13 RIBBON CABLE TO TOP PCB (J7)
A20 CO-AX CABLE TO REAR PNL
INVERT P1 PIN 3
AM IN DISABLE P1 PIN 5
AM IN P2 PIN 1
P2 PIN 2
A1 J15
A1 J5
U31 PIN 8 INVERT
KB
AMPL CONTROL AMP
A12 RIBBON CABLE TO TOP PCB (J6)
A1J4
AMPL P1 PIN 14
P1 PIN 13
AMPL BAL P1 PIN 4
P1 PIN 3
PA BAL P1 PIN 16
P1 PIN 15
DX OFFSET P1 PIN 18
P1 PIN 17
R43 100K
R45 20K
C23 6.8
R44 10K
U13D LF347
R49 100K
U11C
U11D
R35 162K
R33 620
D18
D16
R56 11.8K
R55 324K
R94 5.49K
R51 61.9K
U13B LF347
R50 7.5K
R53 1.78K
R84 100
R46 10K
U13C LF347
Q39A 2N4258 2PL
Q39B
R165 49.9
R166 49.9
R168 100
R169 100
R170 100
R164 100
D31 IN963
C42 .01
C43 .1
C22 .01
R91 100
2V
OFFSET AMP
R196 7.5K
R200 3.74K
R198 909
R199 6.04K
U39B LF412
R85 100
R194 1.82K
R86 825
LOW FREQ AMPL COMP
R191 10K
C115 22
R172 9.1M
R177 330K
R187 2.2M
C102 22
U39A LF412
C88 6.8
C86 6.8
C107 .001
C44 .01
+15V
-15V
0V
-6V
1V



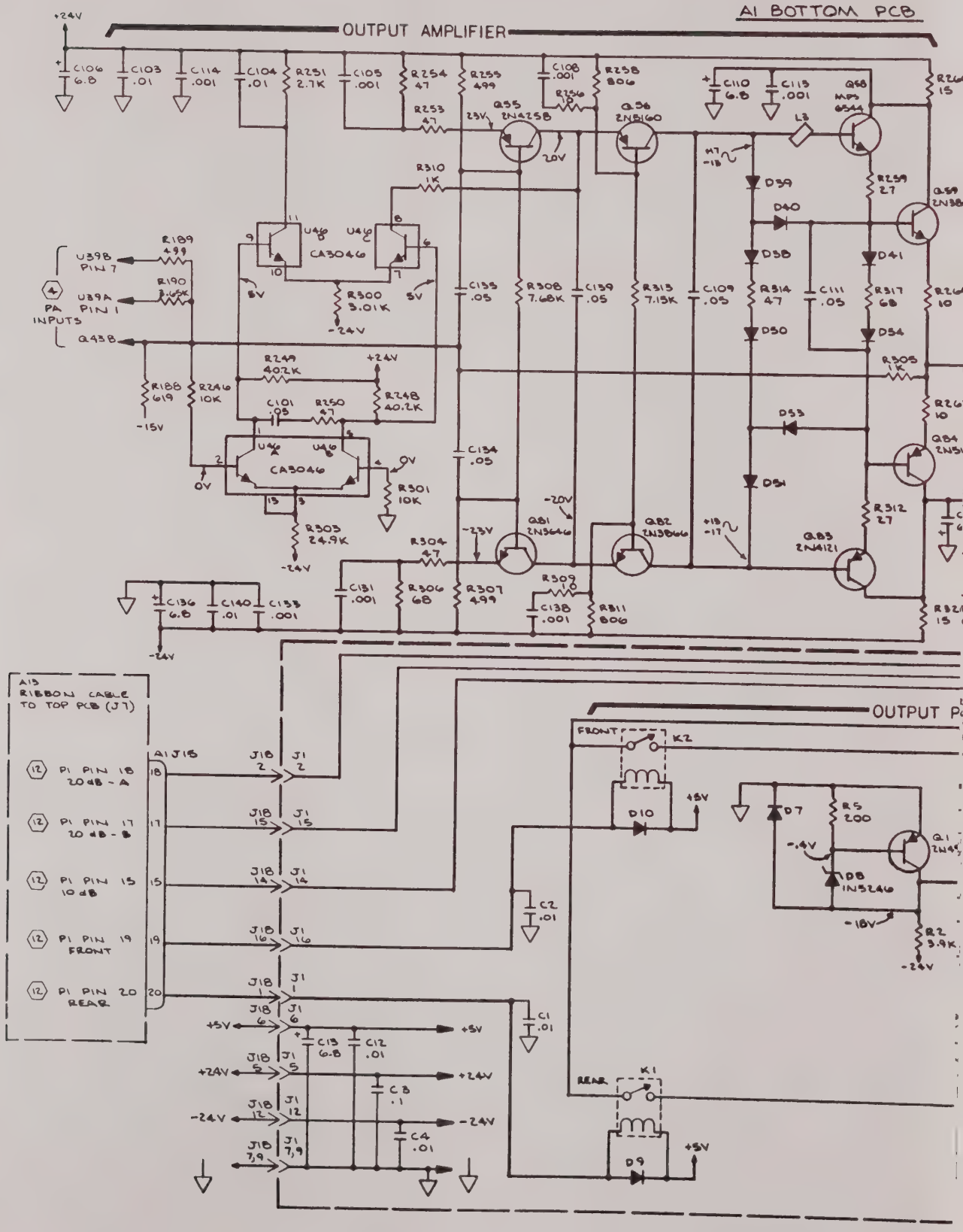
NOTES:

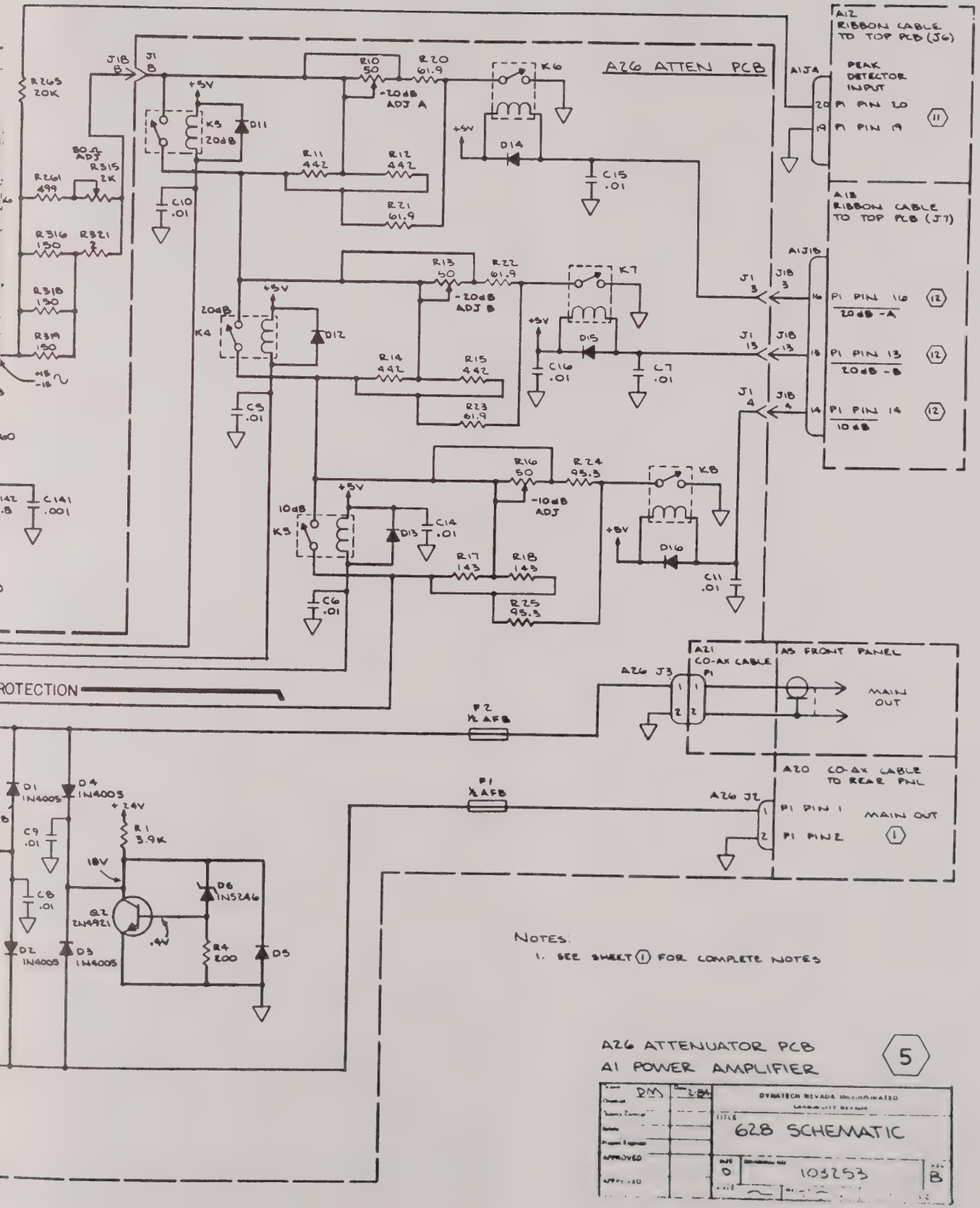
1. SEE SHEET (1) FOR COMPLETE NOTES.

(4)

A1 AMPLITUDE CONTROL

DRAWN DM 7-84	DYNATECH NEVADA INCORPORATED	
APPROVED	TITLE 628 SCHEMATIC	
APPROVED	SIZE D	103253 REV A
	SCALE	WEIGHT SHEET 4 OF 12

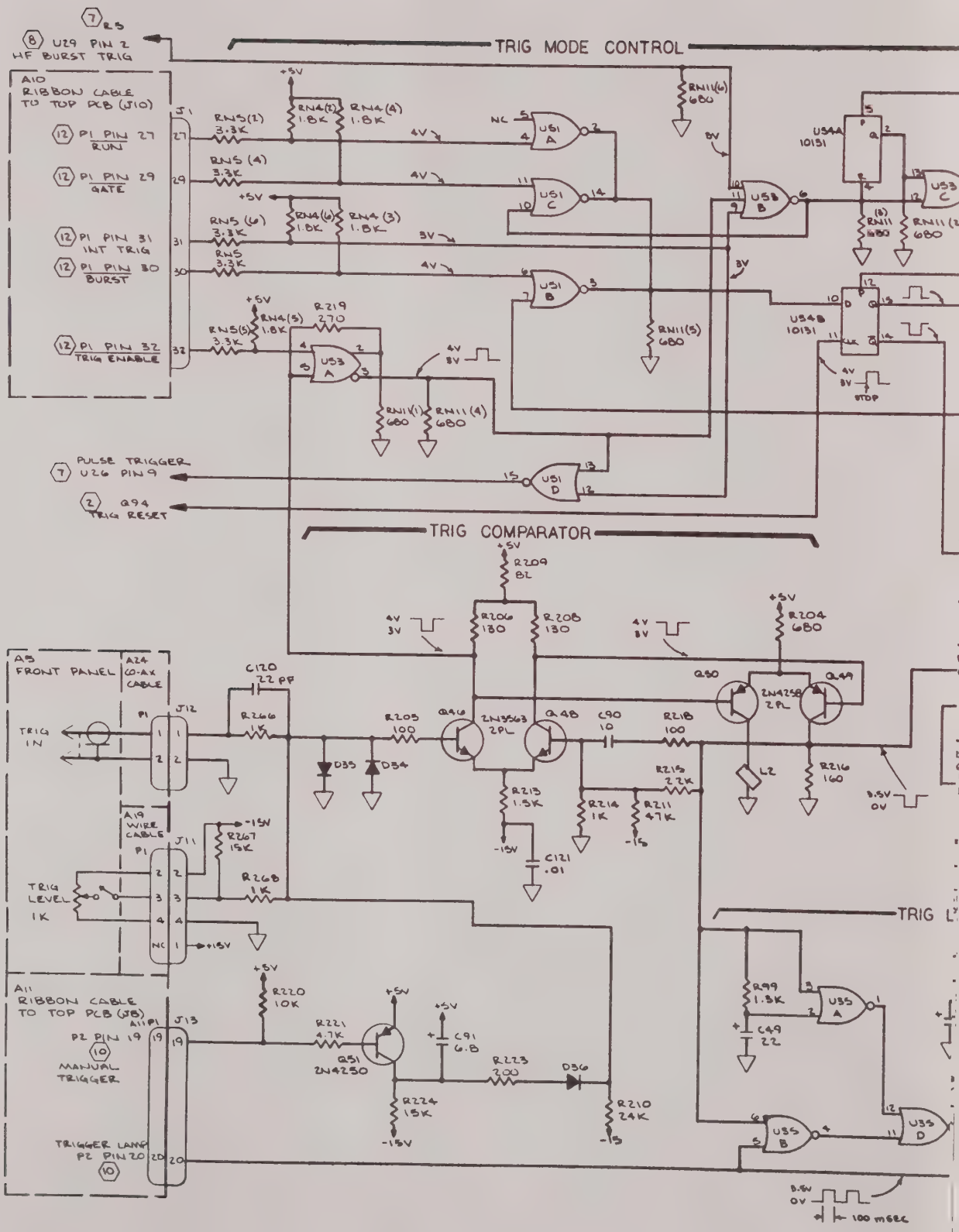

A1 BOTTOM PCB
OUTPUT AMPLIFIER
+24V
C106 6.8
C103 .01
C114 .001
C104 .01
R251 2.7K
C105 .001
R254 47
R255 499
C108 .001
R256 10
R258 806
R253 47
Q55 2N4258
Q56 2N5160
C110 6.8
C113 .001
Q60 MPS 6544
L3
R260 15
R310 1K
D39
D40
D38
D41
D50
D54
R259 27
Q59 2N38
U39B PIN 7
U39A PIN 1
PA INPUTS
R189 499
R190 3.65K
U46 CA3046
R300 3.01K
8V
5V
-24V
C155 .05
R308 7.68K
C159 .05
R313 7.15K
C109 .05
R314 47
C111 .05
R317 68
R260 10
Q43B
R188 619
R246 10K
-15V
R249 402K
+24V
C101 .05
R250 47
R248 40.2K
0V
R301 10K
R303 24.9K
C154 .05
R305 1K
D53
D51
Q84 2N5
R312 27
-20V
-23V
Q81 2N3646
Q82 2N3866
Q83 2N4121
+18
-17
R304 47
R309 1
C131 .001
R306 68
R307 4.99
C138 .001
R311 806
C136 6.8
C140 .01
C133 .001
A1S RIBBON CABLE TO TOP PCB (J7)
A1 J18
P1 PIN 18 20 dB - A
P1 PIN 17 20 dB - B
P1 PIN 15 10 dB
P1 PIN 19 FRONT
P1 PIN 20 REAR
J18 J1
+5V
+24V
-24V
C13 6.8
C12 .01
C3 .1
C4 .01
C1 .01
C2 .01
OUTPUT P
FRONT
K2
D10
D7
R5 200
-4V
D8 IN5246
-18V
R2 3.9K
Q1 2N49
REAR
K1
D9

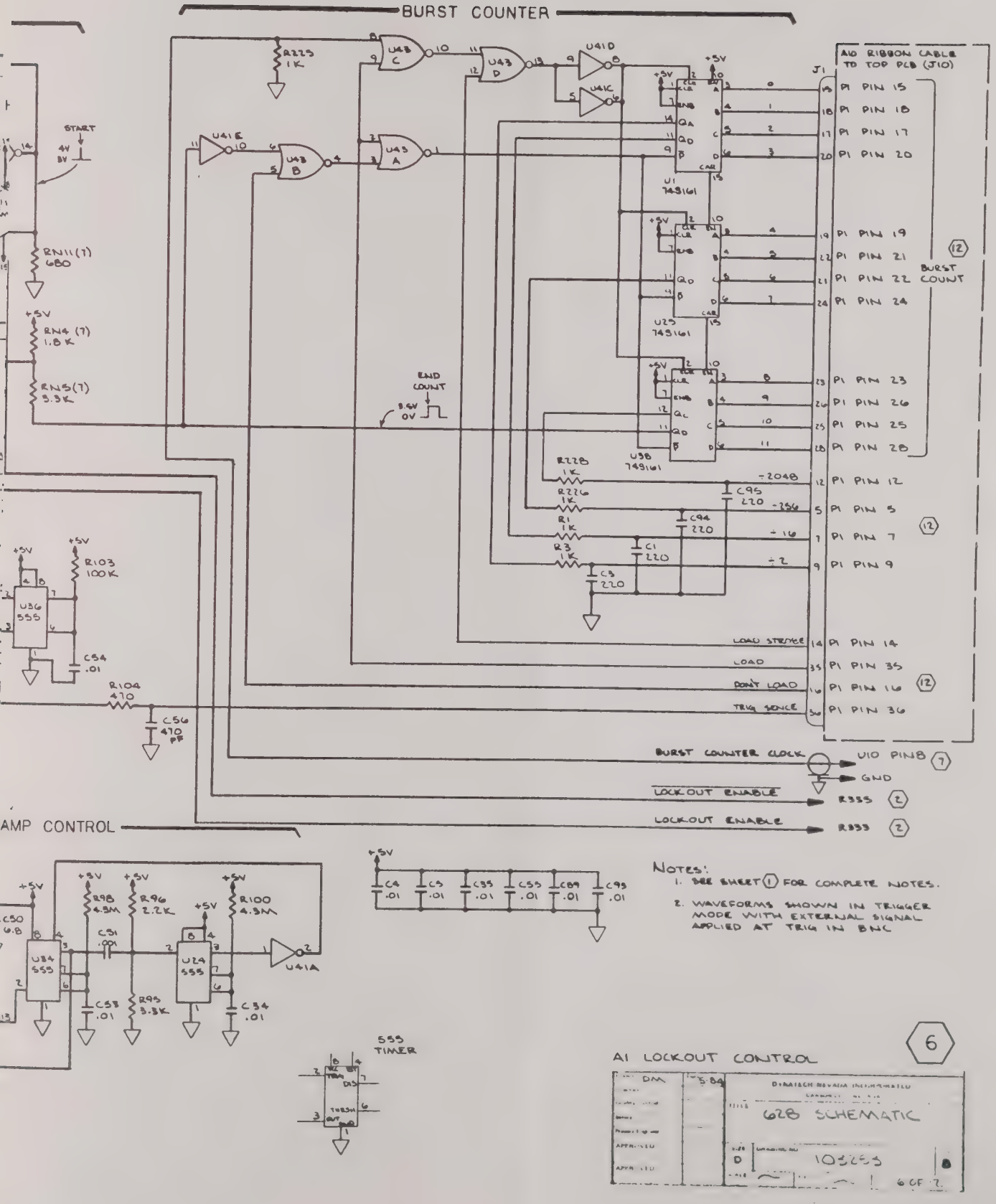


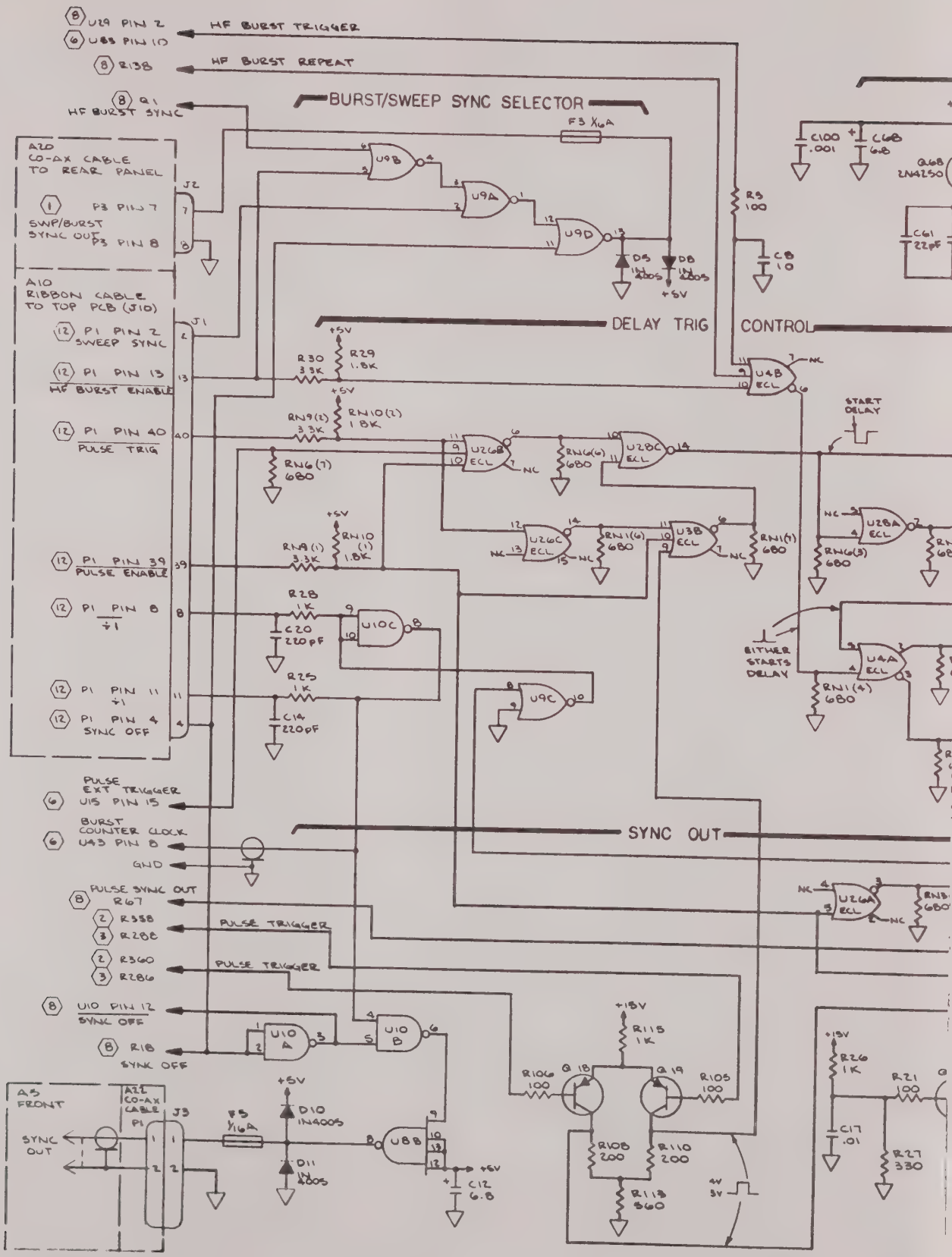
A26 ATTENUATOR PCB
A1 POWER AMPLIFIER

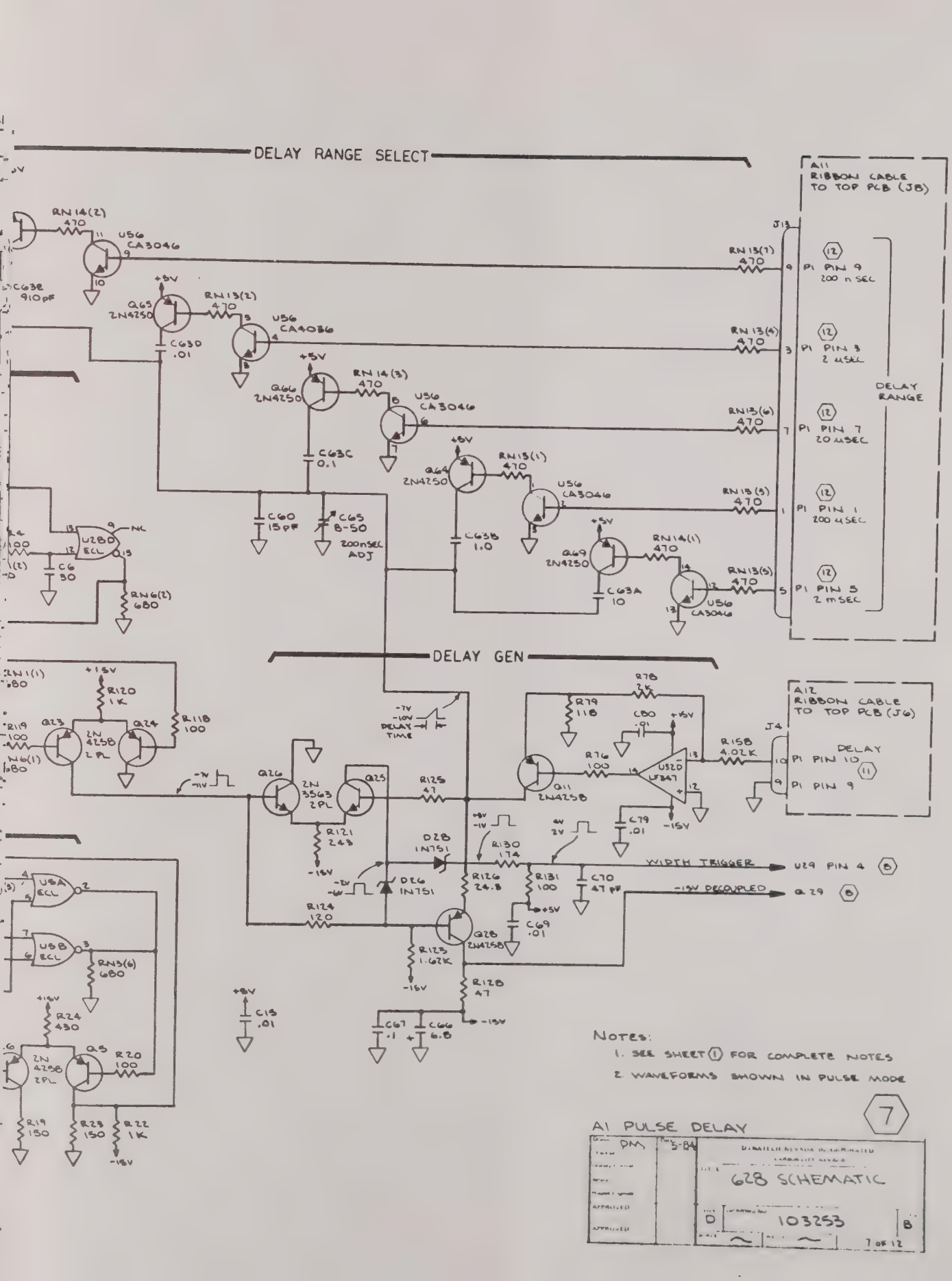
5

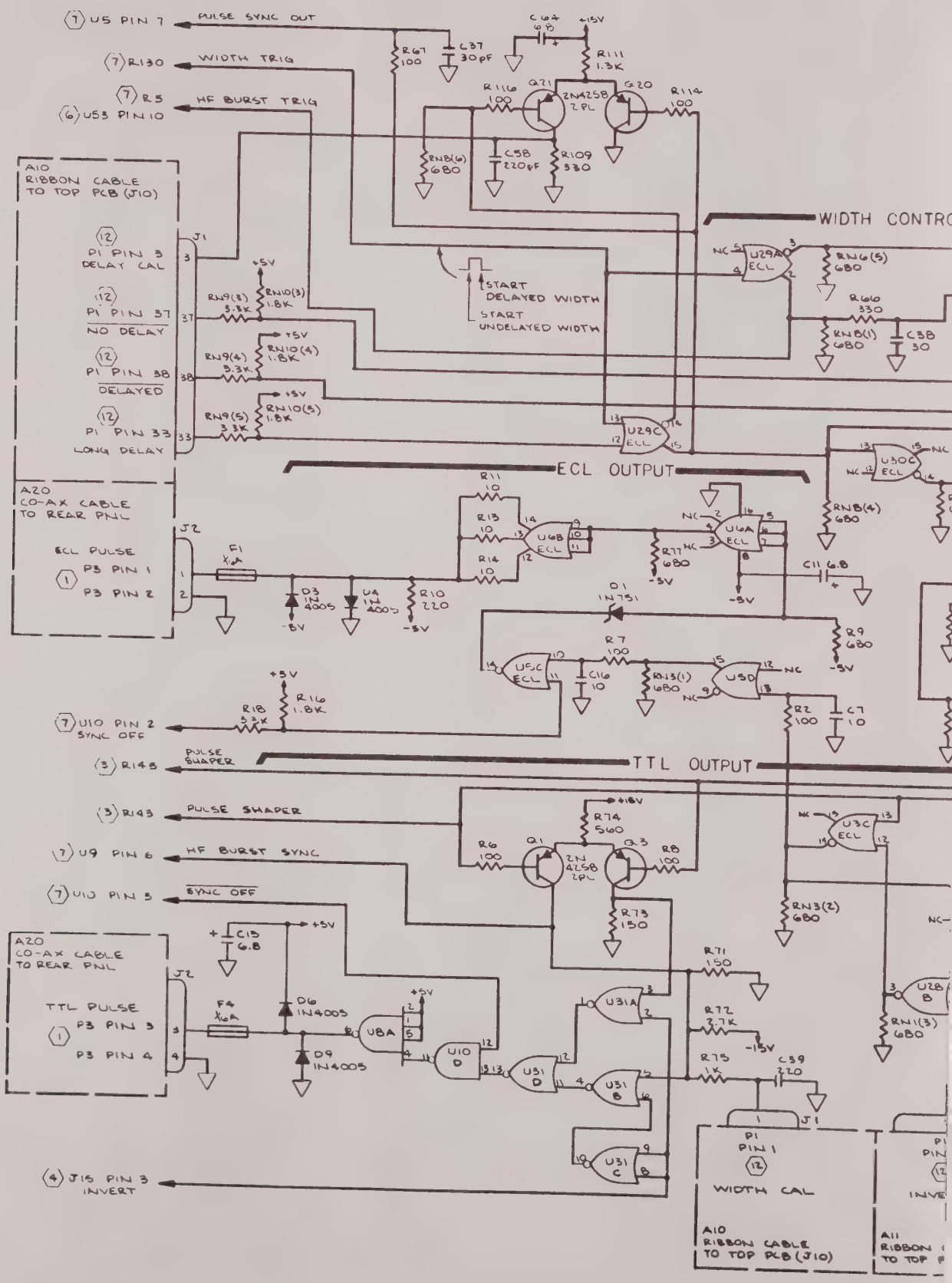
RM	2-84	DYNATECH REVADA INCORPORATED
		TITLE 628 SCHEMATIC
APPROVED		SIZE D 103253 REV B

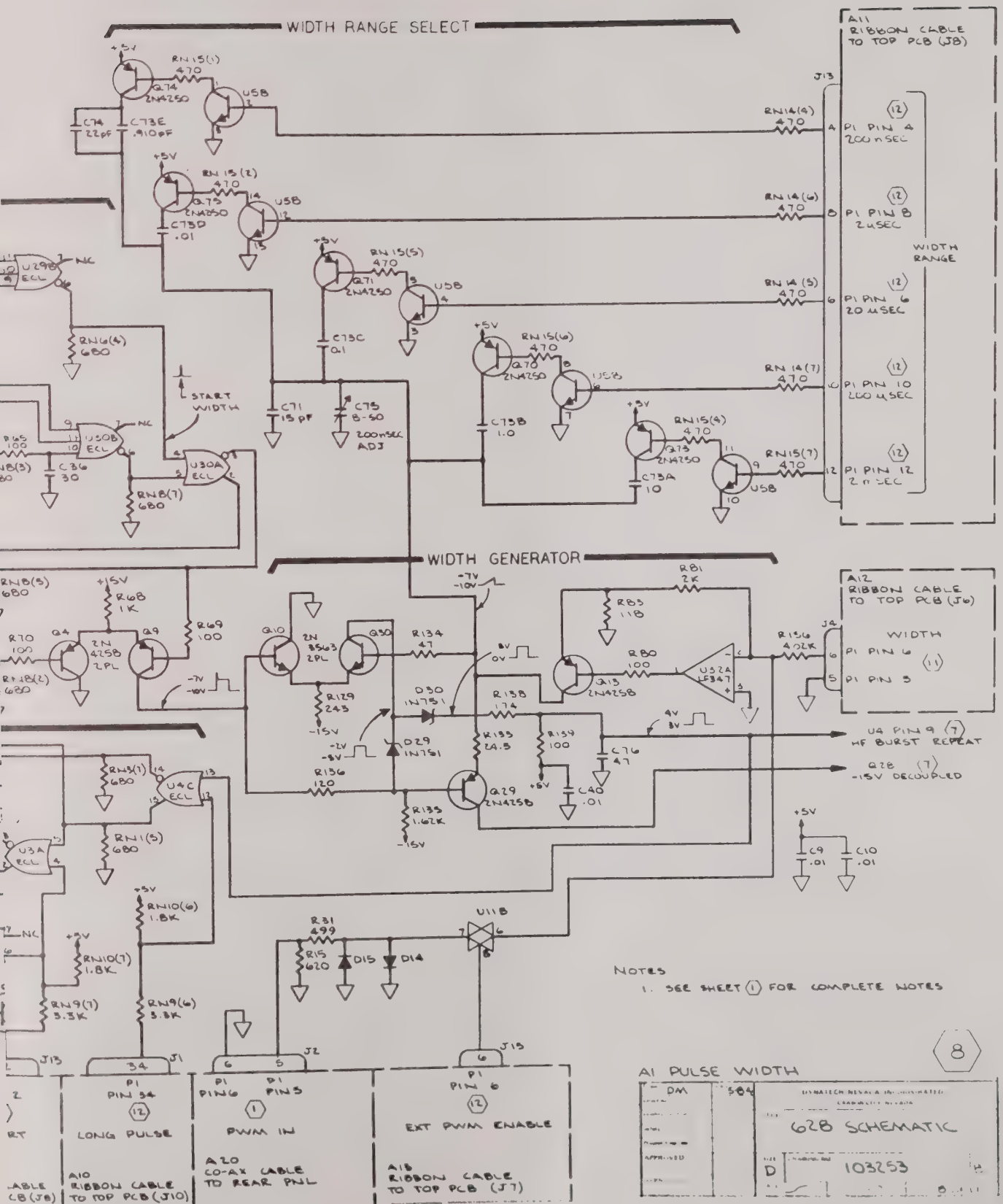

TRIG MODE CONTROL
TRIG COMPARATOR
TRIG L
A10 RIBBON CABLE TO TOP PCB (J10)
A5 FRONT PANEL
A24 CO-AX CABLE
A19 WIRE CABLE
A11 RIBBON CABLE TO TOP PCB (J8)
8 U29 PIN 2 HF BURST TRIG
12 P1 PIN 27 RUN
12 P1 PIN 29 GATE
12 P1 PIN 31 INT TRIG
12 P1 PIN 30 BURST
12 P1 PIN 32 TRIG ENABLE
7 PULSE TRIGGER U26 PIN 9
2 Q94 TRIG RESET
TRIG IN
TRIG LEVEL 1K
P2 PIN 19 10 MANUAL TRIGGER
TRIGGER LAMP P2 PIN 20 10
STOP
100 msec


BURST COUNTER
AMP CONTROL
555 TIMER
A1O RIBBON CABLE TO TOP PCB (J10)
BURST COUNT
END COUNT
START
LOAD STROBE
LOAD
POINT LOAD
TRIG SOURCE
BURST COUNTER CLOCK
LOCKOUT ENABLE
LOCKOUT ENABLE
GND
÷2048
÷256
÷16
÷2
NOTES:
1. SEE SHEET (1) FOR COMPLETE NOTES.
2. WAVEFORMS SHOWN IN TRIGGER MODE WITH EXTERNAL SIGNAL APPLIED AT TRIG IN BNC
A1 LOCKOUT CONTROL
6
628 SCHEMATIC
6 OF 7

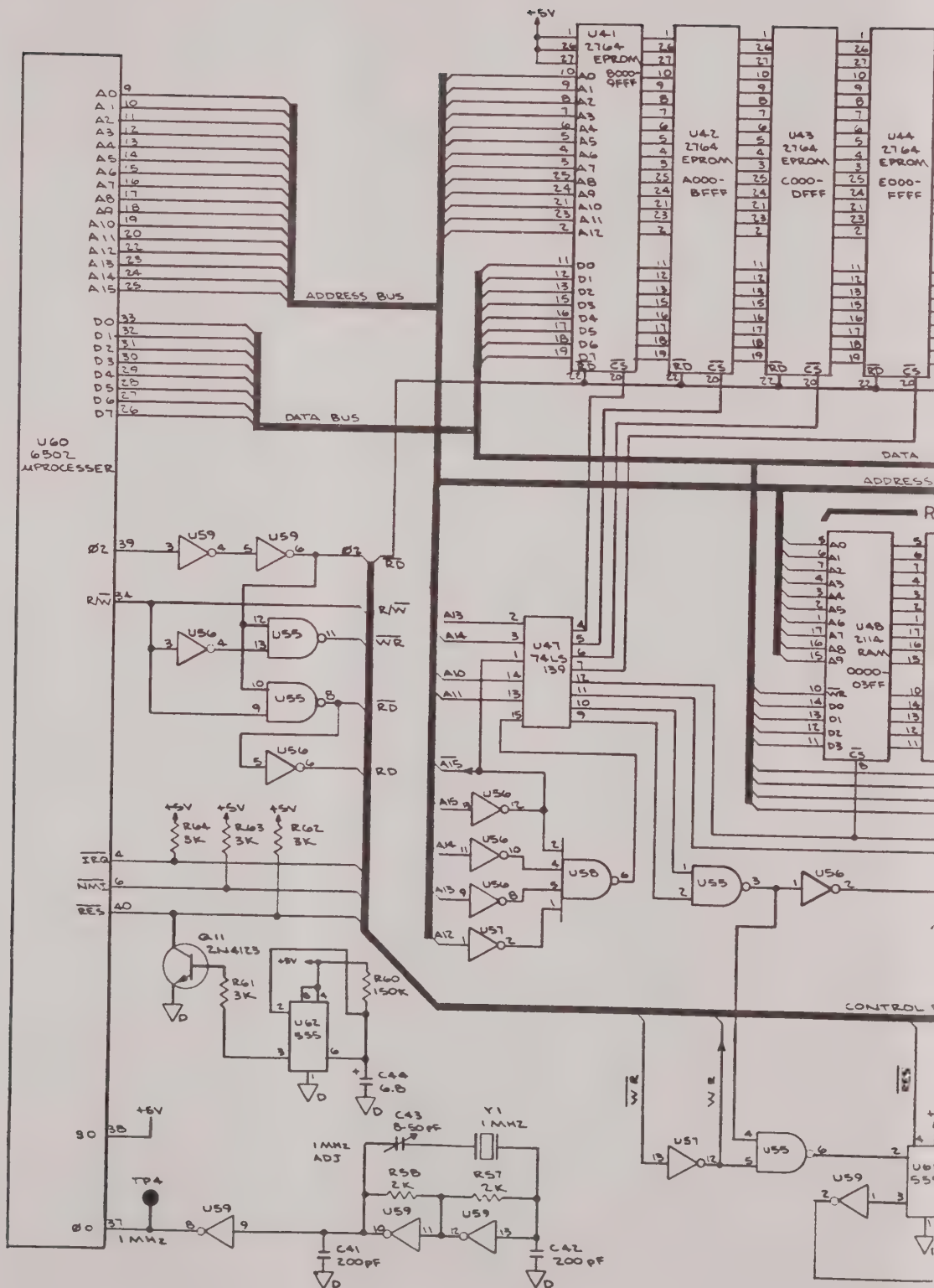

HF BURST TRIGGER
HF BURST REPEAT
HF BURST SYNC
BURST/SWEEP SYNC SELECTOR
A20 CO-AX CABLE TO REAR PANEL
SWP/BURST SYNC OUT
A10 RIBBON CABLE TO TOP PCB (J10)
P1 PIN 2 SWEEP SYNC
P1 PIN 13 HF BURST ENABLE
P1 PIN 40 PULSE TRIG
P1 PIN 39 PULSE ENABLE
P1 PIN 8 ÷1
P1 PIN 11 ÷1
P1 PIN 4 SYNC OFF
DELAY TRIG CONTROL
START DELAY
EITHER STARTS DELAY
SYNC OUT
PULSE EXT TRIGGER U15 PIN 15
BURST COUNTER CLOCK U43 PIN 8
GND
PULSE SYNC OUT R67
PULSE TRIGGER
PULSE TRIGGER
U10 PIN 12 SYNC OFF
R18 SYNC OFF
A5 FRONT
A22 CO-AX CABLE
SYNC OUT
+5V
+15V
+6V

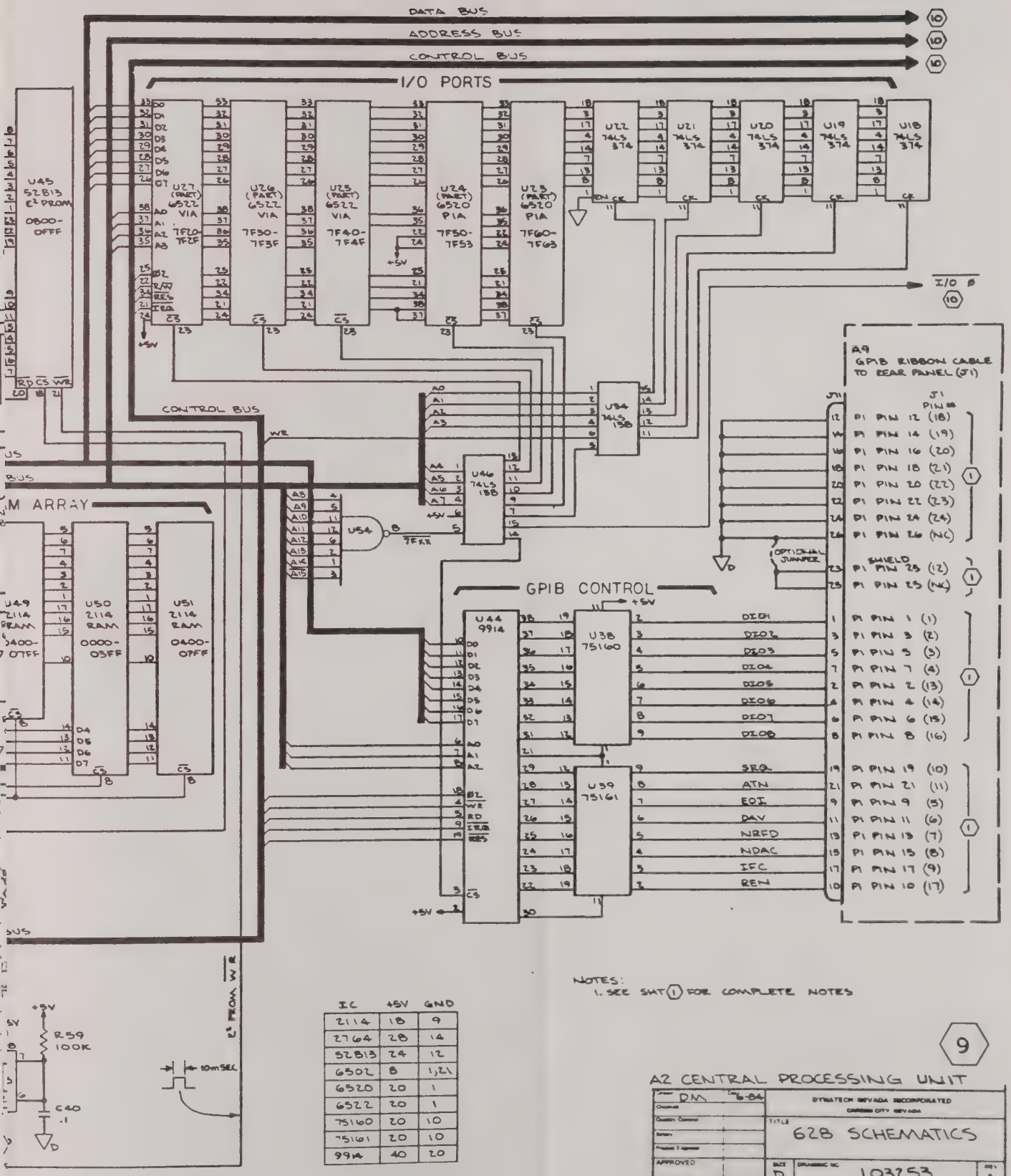

DELAY RANGE SELECT
DELAY GEN
A11 RIBBON CABLE TO TOP PCB (J8)
A12 RIBBON CABLE TO TOP PCB (J6)
RN14(2) 470
U56 CA3046
C63B 910pF
Q65 2N4250
RN13(2) 470
C63D .01
RN13(7) 470
P1 PIN 9 200 n SEC
RN13(4) 470
P1 PIN 3 2 μSEC
Q66 2N4250
RN14(3) 470
C63C 0.1
RN13(6) 470
P1 PIN 7 20 μSEC
DELAY RANGE
Q64 2N4250
RN13(1) 470
C60 15pF
C65 8-50 200nSEC ADJ
RN13(3) 470
P1 PIN 1 200 μSEC
C63B 1.0
Q69 2N4250
RN14(1) 470
C63A 10
RN13(5) 470
P1 PIN 5 2 mSEC
U28D ECL
RN6(2) 680
C6 30
-10V DELAY TIME
R78 2.5
R79 118
C80 .01
R158 4.02K
P1 PIN 10
P1 PIN 9
DELAY
R120 1K
R119 100
Q23
Q24
R118 100
2N 4258 2PL
R76 100
U32D LF347
Q11 2N4250
C79 .01
Q26
Q25
R125 47
R121 243
D28 1N751
R130 174
WIDTH TRIGGER
U29 PIN 4
D26 1N751
R126 24.9
R131 100
C70 47 pF
-15V DECOUPLED
R124 120
Q28 2N4258
C69 .01
R123 1.62K
R128 47
C67 .1
C66 6.8
C13 .01
U8A ECL
U8B ECL
RN3(6) 680
R24 430
Q5
R20 100
R19 150
R23 150
R22 1K
NOTES:
1. SEE SHEET (1) FOR COMPLETE NOTES
2. WAVEFORMS SHOWN IN PULSE MODE
7
A1 PULSE DELAY
5-84
628 SCHEMATIC
D
103253
B
7 OF 12


(7) U5 PIN 7
PULSE SYNC OUT
(7) R130
WIDTH TRIG
(7) R5
(6) U53 PIN 10
HF BURST TRIG
A10 RIBBON CABLE TO TOP PCB (J10)
(12) P1 PIN 3 DELAY CAL
(12) P1 PIN 37 NO DELAY
(12) P1 PIN 38 DELAYED
(12) P1 PIN 33 LONG DELAY
J1
START DELAYED WIDTH
START UNDELAYED WIDTH
WIDTH CONTRO
ECL OUTPUT
A20 CO-AX CABLE TO REAR PNL
ECL PULSE
(1) P3 PIN 1
P3 PIN 2
J2
F1
D3 IN 4005
D4 IN 4005
D1 IN751
(7) U10 PIN 2 SYNC OFF
(3) R145
PULSE SHAPER
TTL OUTPUT
(3) R143
PULSE SHAPER
(7) U9 PIN 6
HF BURST SYNC
(7) U10 PIN 5
SYNC OFF
A20 CO-AX CABLE TO REAR PNL
TTL PULSE
(1) P3 PIN 3
P3 PIN 4
F4
D6 IN4005
D9 IN4005
(4) J15 PIN 3 INVERT
P1 PIN 1
(12) WIDTH CAL
A10 RIBBON CABLE TO TOP PCB (J10)
A11 RIBBON TO TOP


WIDTH RANGE SELECT
WIDTH GENERATOR
A11 RIBBON CABLE TO TOP PCB (J8)
A12 RIBBON CABLE TO TOP PCB (J6)
WIDTH RANGE
START WIDTH
200nSEC ADJ
U4 PIN 9 (7) HF BURST REPEAT
Q28 (7) -15V DECOUPLED
NOTES
1. SEE SHEET (1) FOR COMPLETE NOTES
LONG PULSE
PWM IN
EXT PWM ENABLE
A20 CO-AX CABLE TO REAR PNL
A10 RIBBON CABLE TO TOP PCB (J10)
A18 RIBBON CABLE TO TOP PCB (J7)
A1 PULSE WIDTH
628 SCHEMATIC
103253
8

A2 TOP PCB


U60
6502
μPROCESSER
ADDRESS BUS
DATA BUS
U41
2764
EPROM
8000-
9FFF
U42
2764
EPROM
A000-
BFFF
U43
2764
EPROM
C000-
DFFF
U44
2764
EPROM
E000-
FFFF
U48
2114
RAM
0000-
03FF
U47
74LS
139
U59
U56
U55
U57
U58
U62
555
R64
3K
R63
3K
R62
3K
R61
3K
R60
150K
Q11
2N4123
C40
6.8
C41
200pF
C42
200pF
C43
8-50pF
Y1
1MHZ
1MHZ
ADJ
R58
2K
R57
2K
TP4
+5V
RD
R/W
WR
IRQ
NMI
RES
Ø2
Ø0
1MHZ
DATA
ADDRESS
CONTROL



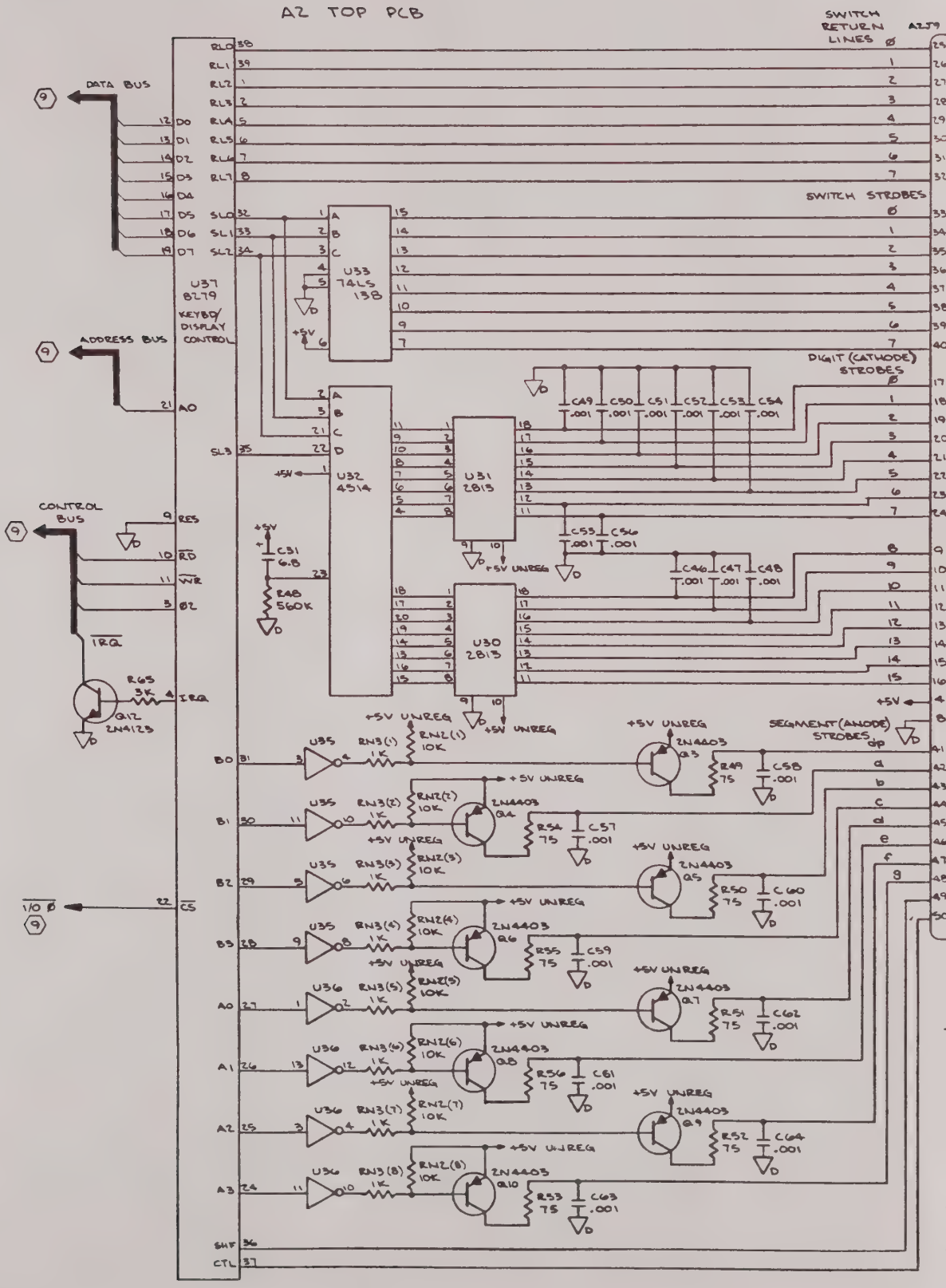
IC	+5V	GND
2114	18	9
2764	28	14
52B13	24	12
6502	8	1,21
6520	20	1
6522	20	1
75160	20	10
75161	20	10
9914	40	20

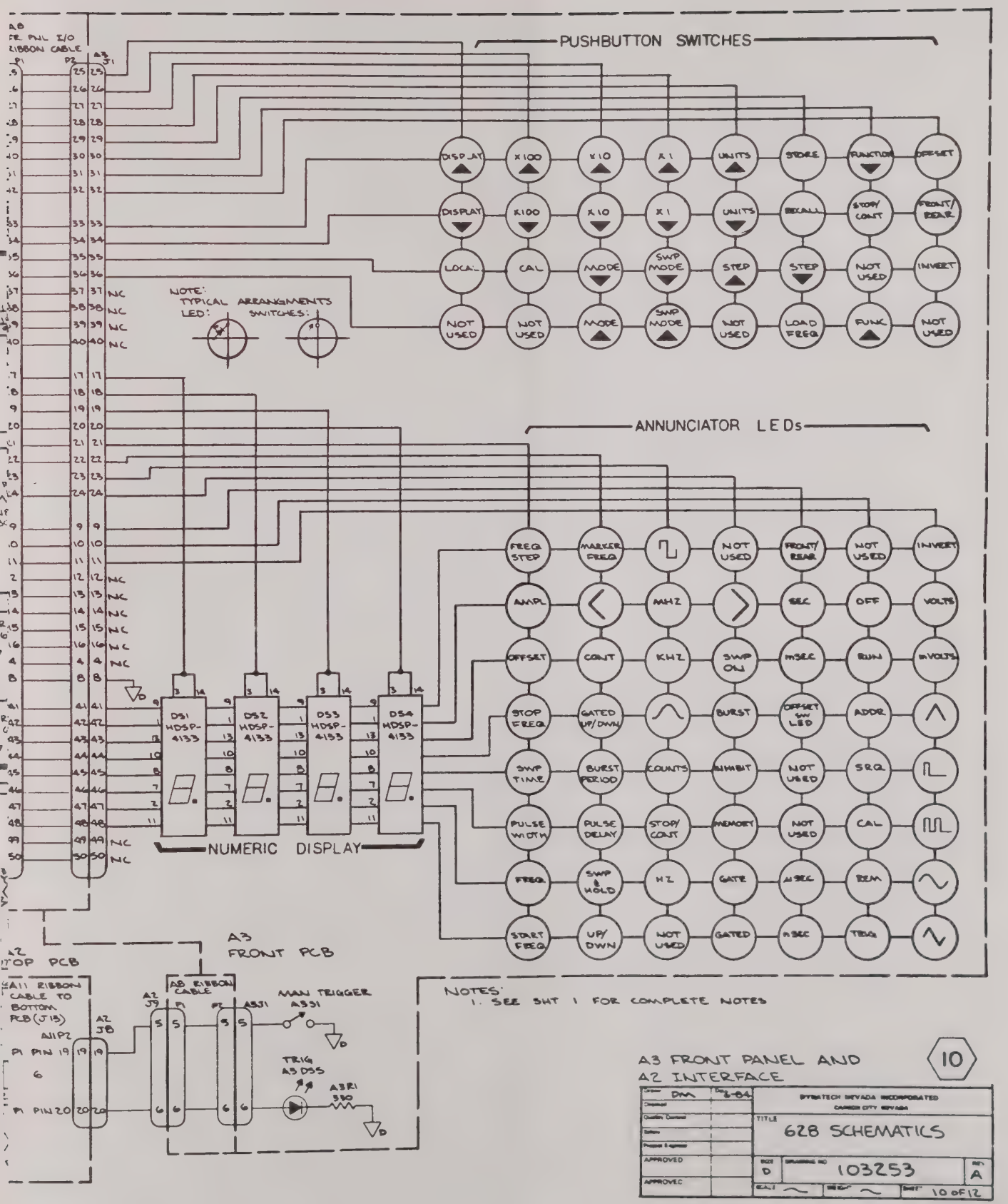
NOTES:
1. SEE SHT (1) FOR COMPLETE NOTES

9

A2 CENTRAL PROCESSING UNIT

DM 6-84	DYNATECH NEVADA INCORPORATED	
	TITLE: 628 SCHEMATICS	
APPROVED	SIZE D	DRAWING NO 103253
APPROVED	SCALE ~	SHEET 9 OF 12


A2 TOP PCB
SWITCH RETURN LINES
A2J9
SWITCH STROBES
DIGIT (CATHODE) STROBES
SEGMENT (ANODE) STROBES dp
DATA BUS
ADDRESS BUS
CONTROL BUS
U37 8279 KEYBD/ DISPLAY CONTROL
U33 74LS 138
U32 4514
U31 2813
U30 2813
U35
U36
RN3(1) 1K
RN2(1) 10K
RN3(2) 1K
RN2(2) 10K
RN3(3) 1K
RN2(3) 10K
RN3(4) 1K
RN2(4) 10K
RN3(5) 1K
RN2(5) 10K
RN3(6) 1K
RN2(6) 10K
RN3(7) 1K
RN2(7) 10K
RN3(8) 1K
RN2(8) 10K
+5V UNREG
2N4403
R49 75
R54 75
R50 75
R55 75
R51 75
R56 75
R52 75
R53 75
C58 .001
C57 .001
C60 .001
C59 .001
C62 .001
C61 .001
C64 .001
C63 .001
C49 .001
C50 .001
C51 .001
C52 .001
C53 .001
C54 .001
C55 .001
C56 .001
C46 .001
C47 .001
C48 .001
C31 6.8
R48 560K
R65 3K
Q12 2N4123
IRQ
RES
RD
WR
Ø2
CS
SHF
CTL
RL0
RL1
RL2
RL3
RL4
RL5
RL6
RL7
SL0
SL1
SL2
SL3
A0
D0
D1
D2
D3
D4
D5
D6
D7

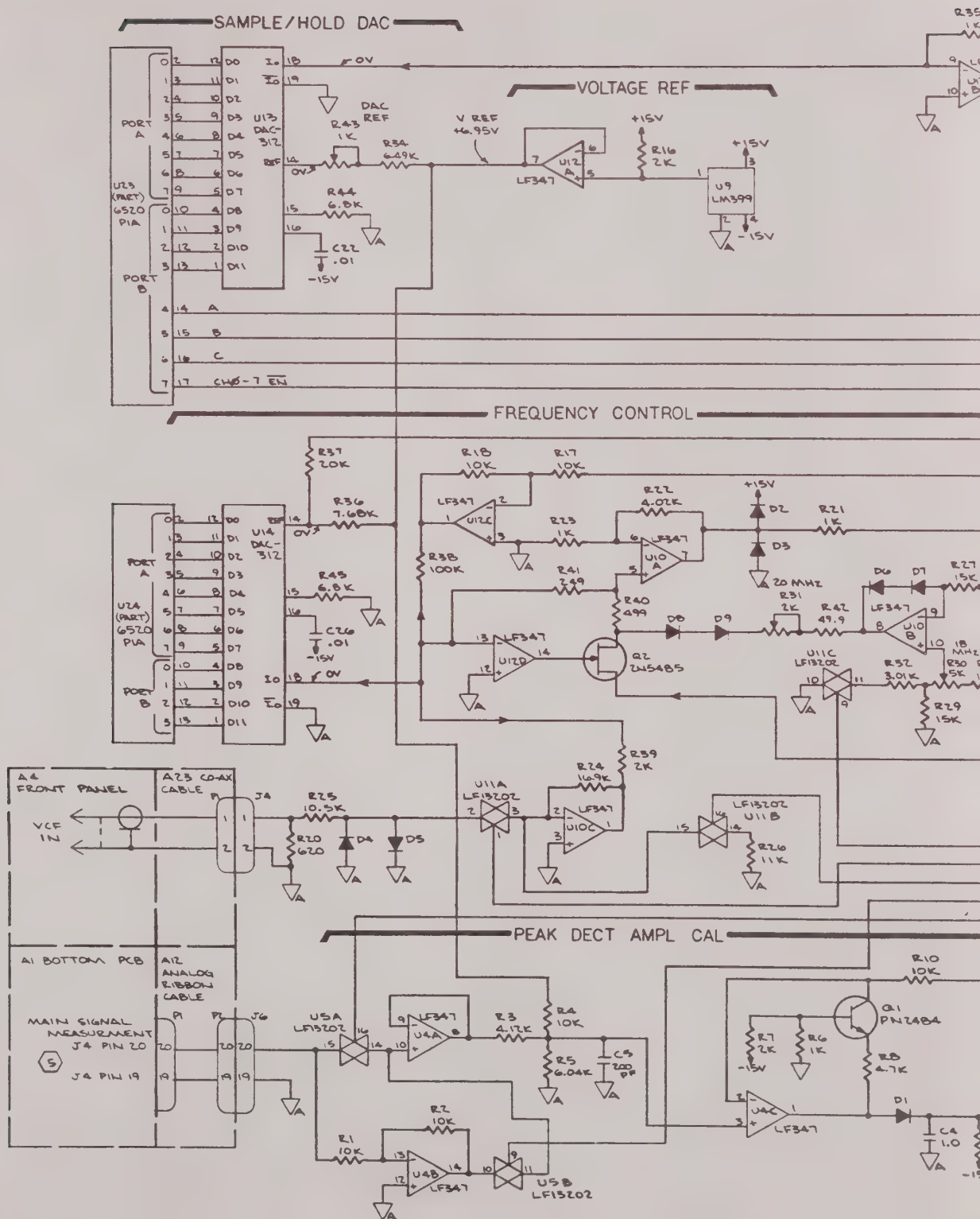


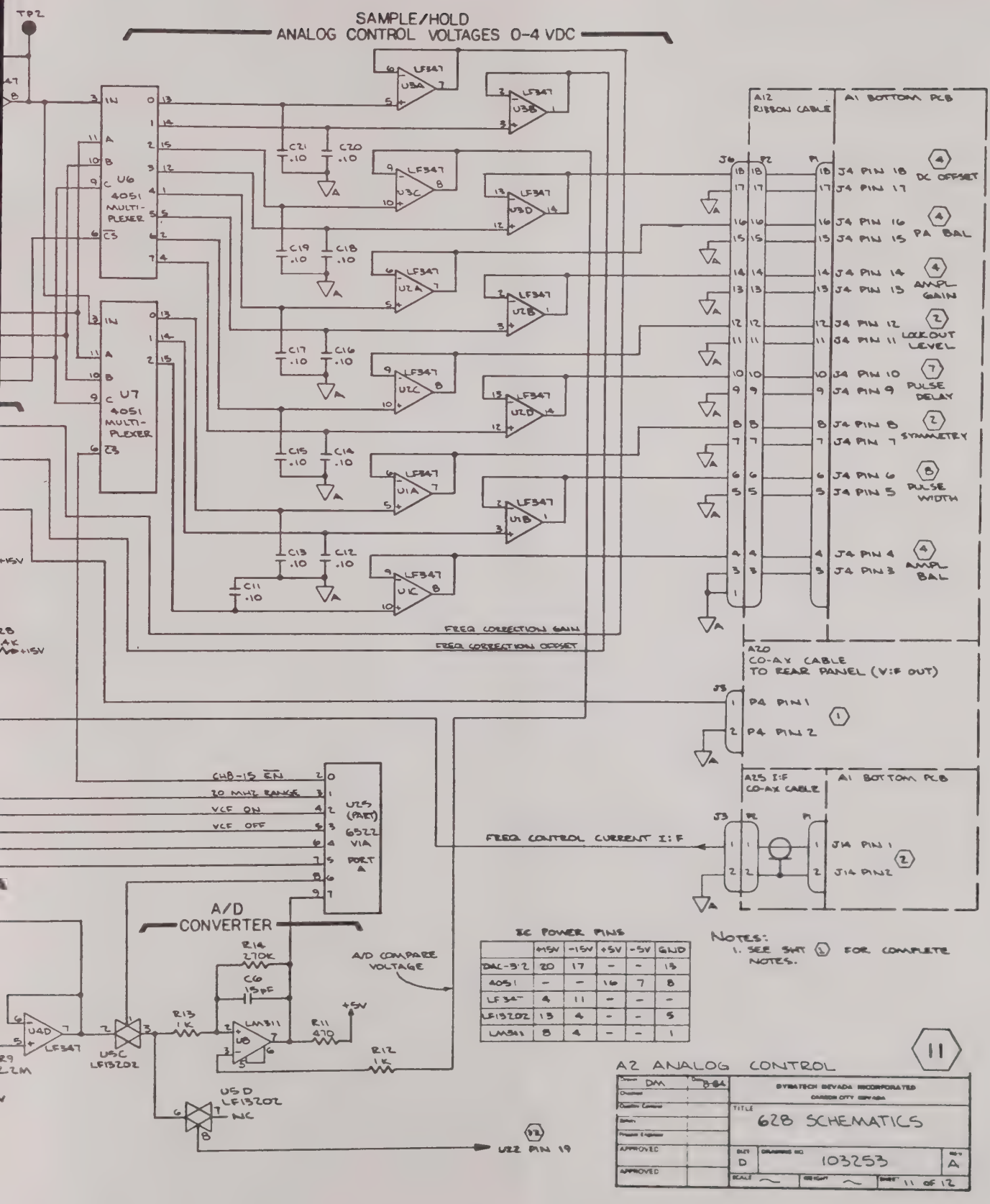
A3 FRONT PANEL AND A2 INTERFACE

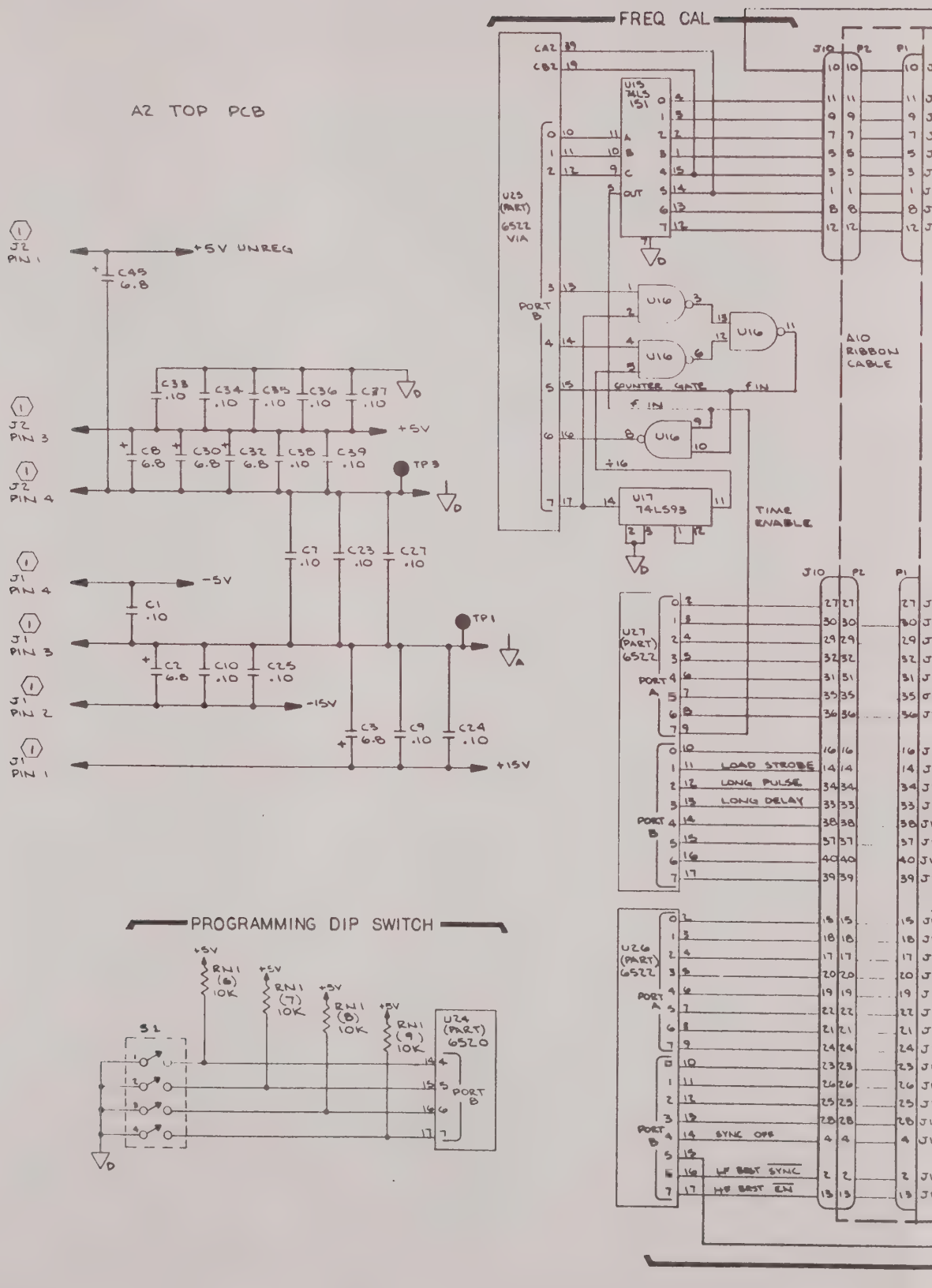
10

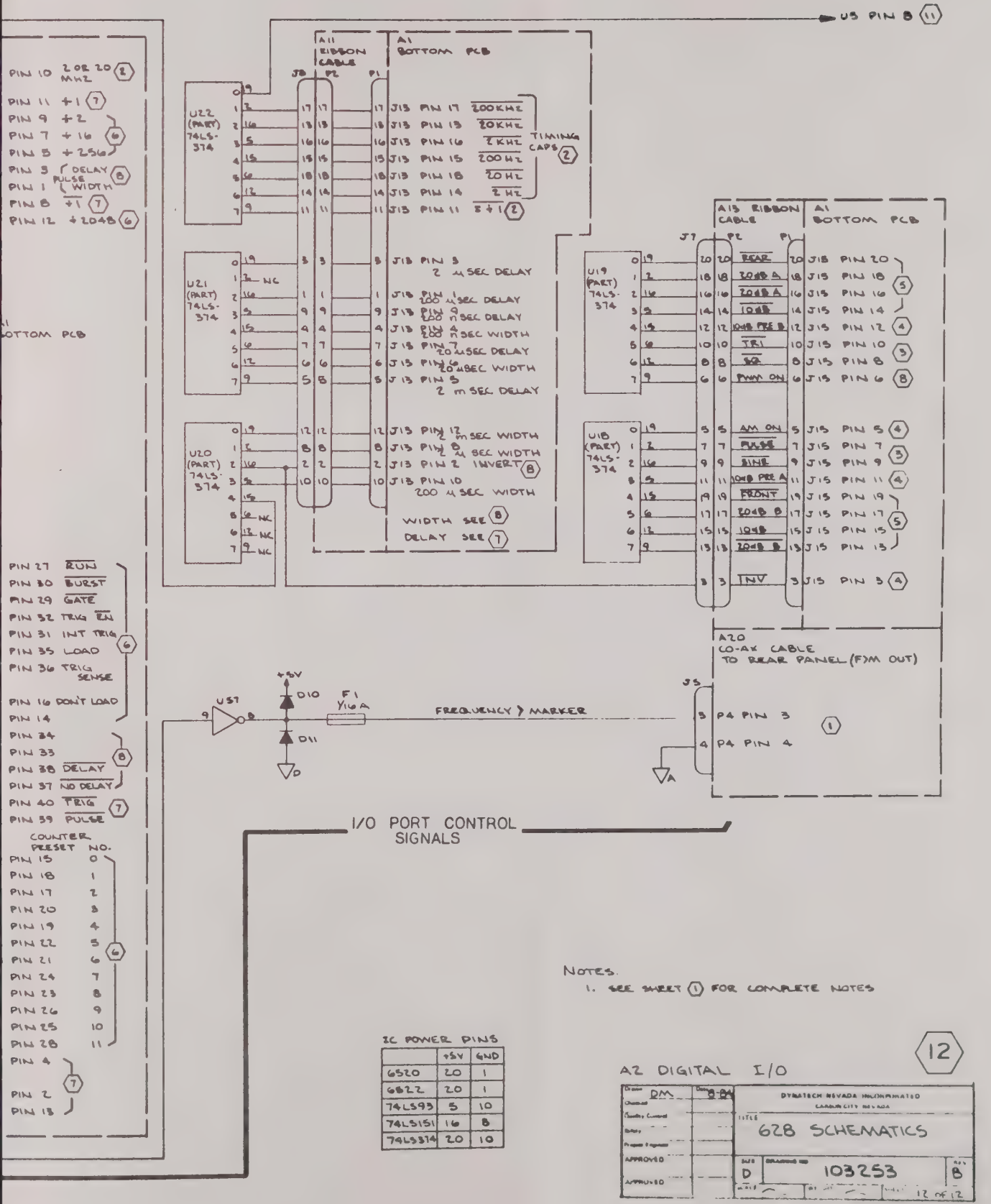
Drawn DM	Date 8-84	TEKTRONIX NEVADA INCORPORATED CARSON CITY NEVADA	
Checked			
Quality Control		TITLE 628 SCHEMATICS	
Editor			
Project Engineer			
APPROVED		SIZE D	DRAWING NO 103253
APPROVED		SCALE	WEIGHT
			SHEET 10 OF 12

A2 TOP PCB


SAMPLE/HOLD DAC
VOLTAGE REF
FREQUENCY CONTROL
PEAK DECT AMPL CAL
PORT A
PORT B
U23 (PART) 6520 PIA
U24 (PART) 6520 PIA
U13 DAC-312
U14 DAC-312
DAC REF
V REF +6.95V
+15V
-15V
0V
LF347
LM399
R43 1K
R34 6.49K
R44 6.8K
C22 .01
R37 20K
R36 7.68K
R45 6.8K
C26 .01
R18 10K
R17 10K
R22 4.02K
R23 1K
R38 100K
R41 249
R40 499
R21 1K
R31 2K
R42 49.9
R32 3.01K
R30 5K
R29 15K
R27 15K
R39 2K
R24 10.9K
R26 11K
R25 10.5K
R20 620
D2
D3
D4
D5
D6
D7
D8
D9
20 MHz
18 MHz
Q2 2N5485
A4 FRONT PANEL
A23 COAX CABLE
VCF IN
J4
A1 BOTTOM PCB
A12 ANALOG RIBBON CABLE
MAIN SIGNAL MEASURMENT
J4 PIN 20
J4 PIN 19
J6
U5A LF13202
U5B LF13202
R3 4.12K
R4 10K
R5 6.04K
C5 200 pF
R2 10K
R1 10K
R10 10K
Q1 PN2484
R7 2K
R6 1K
R8 4.7K
C4 1.0
D1


SAMPLE/HOLD
ANALOG CONTROL VOLTAGES 0-4 VDC
TP2
U6
4051
MULTI-
PLEXER
U7
4051
MULTI-
PLEXER
LF347
U3A
U3B
U3C
U3D
U2A
U2B
U2C
U2D
U1A
U1B
U1C
C21 .10
C20 .10
C19 .10
C18 .10
C17 .10
C16 .10
C15 .10
C14 .10
C13 .10
C12 .10
C11 .10
FREQ CORRECTION GAIN
FREQ CORRECTION OFFSET
A12
RIBBON CABLE
A1 BOTTOM PCB
J4 PIN 18
J4 PIN 17
J4 PIN 16
J4 PIN 15
J4 PIN 14
J4 PIN 13
J4 PIN 12
J4 PIN 11
J4 PIN 10
J4 PIN 9
J4 PIN 8
J4 PIN 7
J4 PIN 6
J4 PIN 5
J4 PIN 4
J4 PIN 3
DC OFFSET
PA BAL
AMPL GAIN
LOCKOUT LEVEL
PULSE DELAY
SYMMETRY
PULSE WIDTH
AMPL BAL
A20
CO-AX CABLE
TO REAR PANEL (V:F OUT)
P4 PIN 1
P4 PIN 2
A25 I:F
CO-AX CABLE
A1 BOTTOM PCB
FREQ CONTROL CURRENT I:F
J14 PIN 1
J14 PIN 2
CHB-15 EN
20 MHZ RANGE
VCF ON
VCF OFF
U25 (PART)
6522
VIA
PORT A
A/D
CONVERTER
A/D COMPARE VOLTAGE
R14 270K
C60 15pF
R13 1K
R11 470
R12 1K
+5V
U4D
LF347
U5C
LF13202
U8
LM311
U5D
LF13202
N/C
U22 PIN 19
IC POWER PINS
DAC-312 20 17 - - 19
4051 - - 16 7 8
LF347 4 11 - - -
LF13202 13 4 - - 5
LM311 8 4 - - 1
NOTES:
1. SEE SHT (1) FOR COMPLETE NOTES.
A2 ANALOG CONTROL
DYNATECH NEVADA INCORPORATED
TITLE
628 SCHEMATICS
DWG NO 103253
SIZE D
REV A
SHEET 11 OF 12


A2 TOP PCB
FREQ CAL
PROGRAMMING DIP SWITCH
+5V UNREG
-5V
-15V
+15V
+5V
C49 6.8
C38 .10
C34 .10
C35 .10
C36 .10
C37 .10
C8 6.8
C30 6.8
C32 6.8
C38 .10
C39 .10
C7 .10
C23 .10
C27 .10
C1 .10
C2 6.8
C10 .10
C25 .10
C3 6.8
C9 .10
C24 .10
TP3
TP1
U19 74LS 151
U23 (PART) 6522 VIA
U16
U17 74LS93
COUNTER GATE
F IN
÷16
TIME ENABLE
A10 RIBBON CABLE
U27 (PART) 6522
U26 (PART) 6522
U24 (PART) 6520
PORT A
PORT B
LOAD STROBE
LONG PULSE
LONG DELAY
SYNC OPB
LF BAST SYNC
HF BAST EN
S1
RN1 (6) 10K
RN1 (7) 10K
RN1 (8) 10K
RN1 (9) 10K
J10
P2
P1



NOTES.

1. SEE SHEET (1) FOR COMPLETE NOTES

IC POWER PINS

	+5V	GND
6520	20	1
6822	20	1
74LS93	5	10
74LS151	16	8
74LS374	20	10

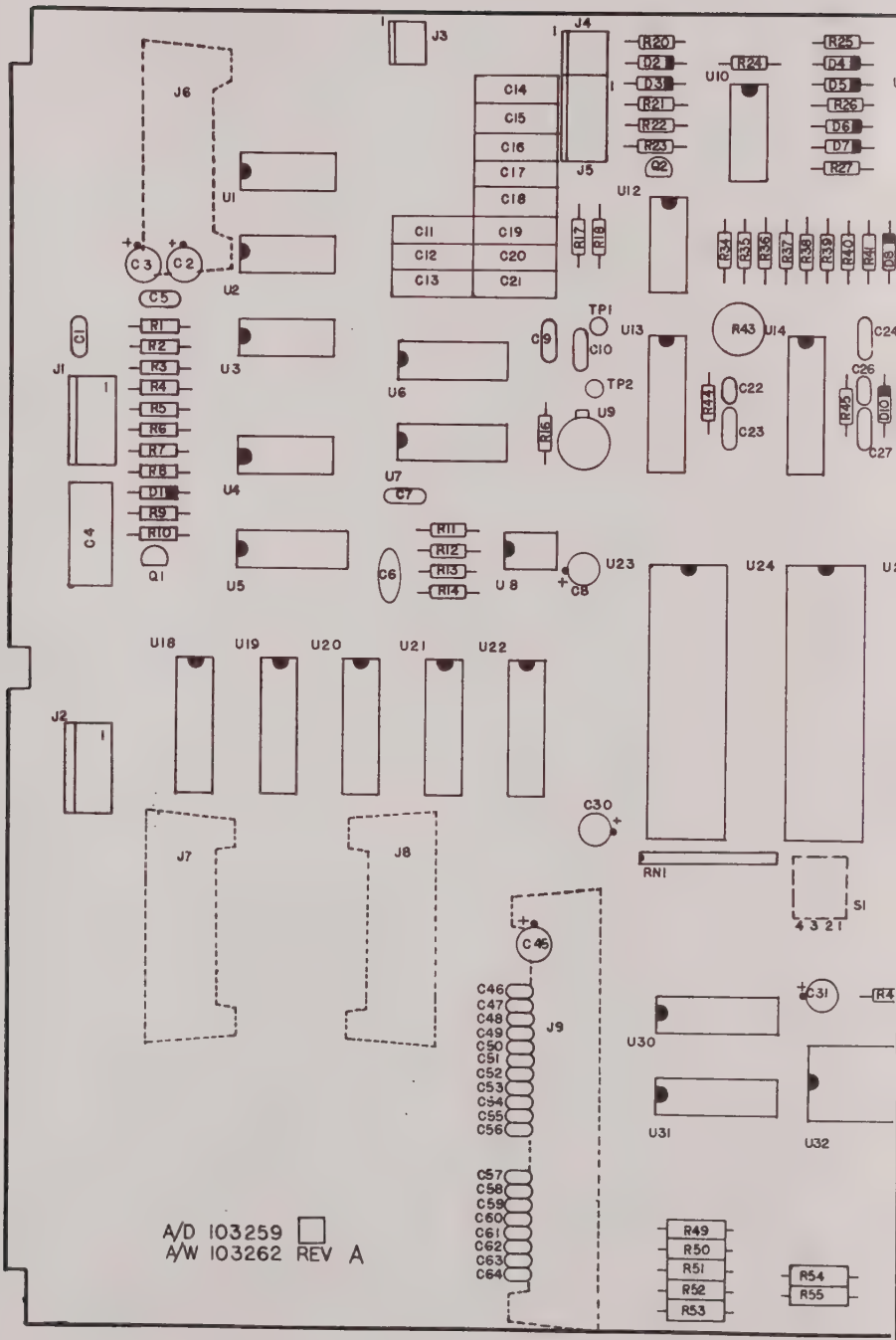
(12)

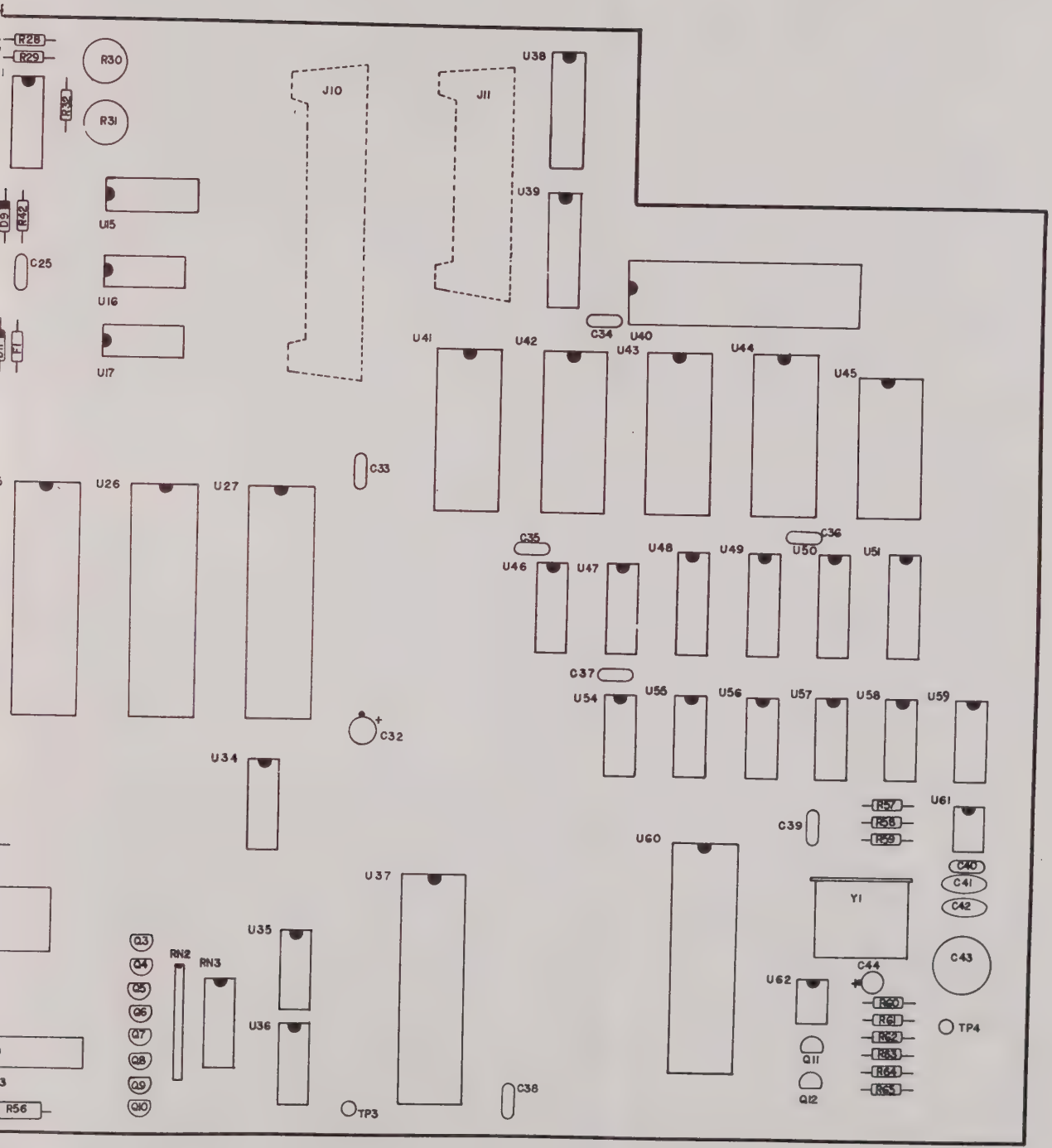
A2 DIGITAL I/O

Drawn DM		DYNATECH NEVADA INCORPORATED
Checked		CARSON CITY NEVADA
Quality Control		TITLE 628 SCHEMATICS
Date		
Project Engineer		
APPROVED		SIZE D — DRAWING NO 103253 — REV B
APPROVED		SCALE — DO NOT SCALE — SHEET 12 OF 12

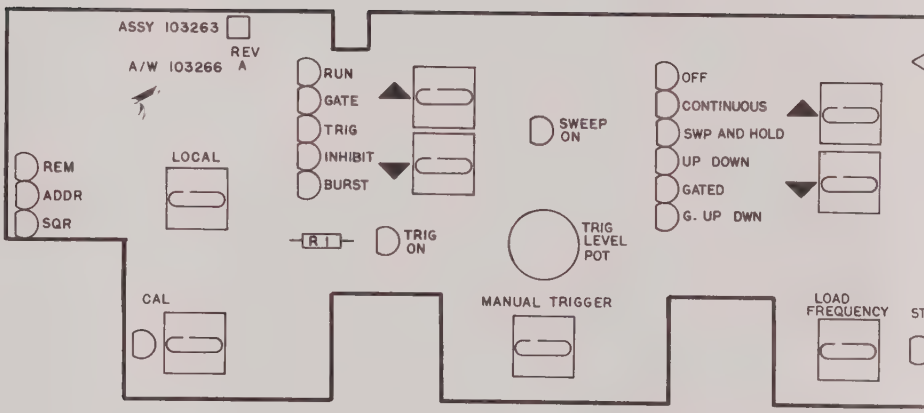
ASSY 103255
A/W 103258
BOTT

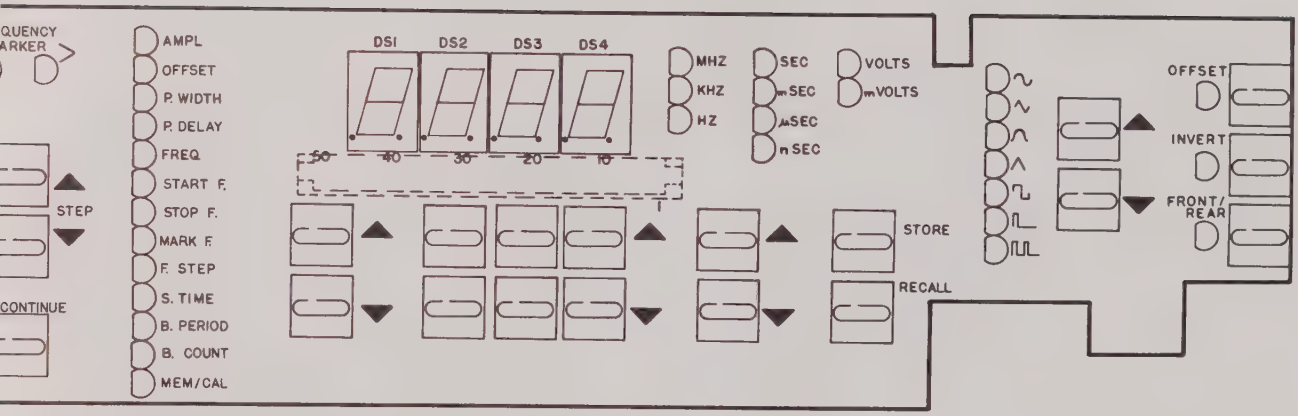
OM PCB


A/D 103259
A/W 103262 REV A


R28
R29
R30
R31
R32
D9
R42
C25
U15
U16
U17
F1
J10
J11
U38
U39
C34
U40
U41
U42
U43
U44
U45
C33
U26
U27
C35
C36
U46
U47
U48
U49
U50
U51
C37
U54
U55
U56
U57
U58
U59
C32
U34
U61
R57
R58
R59
C39
U60
C40
C41
C42
Y1
C43
C44
U62
R60
R61
R62
R63
R64
R65
TP4
Q11
Q12
U37
U35
U36
Q3
Q4
Q5
Q6
Q7
Q8
Q9
Q10
RN2
RN3
TP3
C38
R56

TOP PCB


ASSY 103263
REV A
A/W 103266
RUN
GATE
TRIG
INHIBIT
BURST
SWEEP ON
OFF
CONTINUOUS
SWP AND HOLD
UP DOWN
GATED
G. UP DWN
REM
ADDR
SQR
LOCAL
R1
TRIG ON
TRIG LEVEL POT
CAL
MANUAL TRIGGER
LOAD FREQUENCY


QUENCY
ARKER
STEP
CONTINUE
AMPL
OFFSET
P. WIDTH
P. DELAY
FREQ
START F.
STOP F.
MARK F.
F. STEP
S. TIME
B. PERIOD
B. COUNT
MEM/CAL
DS1
DS2
DS3
DS4
50
40
30
20
10
MHZ
KHZ
HZ
SEC
mSEC
μSEC
nSEC
VOLTS
mVOLTS
STORE
RECALL
OFFSET
INVERT
FRONT/
REAR

DISPLAY PCB

SECTION 6

PARTS LIST

FRONT PANEL PRINTED CIRCUIT BOARD ASSEMBLY

REF DES	DESCRIPTION	PART NUMBER	MFC
	DISP 7 SEGMENT	2410-0007	28480
	LED YELLOW	2106-0025	14936
	SWITCH OBROUND BLACK	2505-0038	
	INTERNAL CABLE ASSEMBLIES		
A008	FP I/O RIBBON CABLE	3010-0086H	34511
A009	GPIB RIBBON CABLE	3010-00085H	34511
A010	PULSE RIBBON CABLE	3010-0087H	34511
1010	RANGE RIBBON CABLE	3010-0089H	34511
A011	ANALOG RIBBON CABLE	3010-0088H	34511
A013	FUNCTION RIBBON CABLE	3010-0090H	34351
A015	XFMR PRIMARY CABLE	3010-0093H	34511
A016	XFMR SECONDARY CABLE	3010-0083H	34511
A017	15V P/S ITCON CABLE	3010-0091H	34511
A018	5V P/S ITCON CABLE	3010-0092H	34511
A019	TRIG LEVEL POT ASSY	3010-0078H	34511
A020	REAR BNC CO-AX	3010-0084H	34511
A021	F.P. MAIN OUT CO-AX	3010-0081H	34511
A022	SYNC OUT CO-AX	3010-0082H	34511
A023	VCF IN CO-AX	3010-0080H	34511
A024	TRIG IN CO-AX	3010-0079H	34511
A025	I:F CO-AX CABLE	3010-0094H	34511
	CHASSIS MOUNTED PARTS		
	628 FRONT PANEL	50001-0155H	34511
	HINGE ASSEMBLY	4717-0005	34511
	FAN	4102-0005	60856
	FAN AIR FILTER	4102-0006H	34511
	FAN FILTER COVER	5008-0168H	34511
	POWER CORD	3010-0006	16428
	POWER SWITCH	2505-00030	82389
	PUSHBUTTON, POWER SWITCH	2505-0029	82389
	DISPLAY LENS	5027-0056H	34511
	BNC CONNECTOR	2706-0019	91836
	D WASHER BNC	4711-6019	34511
	KNOB SMALL 1/8 IN.	4902-0037	32767
	POWER TRANSFORMER	1201-0062	34511
	POWER LINE MODULE	1202-0001	56289
	GPIB STANDOFF	4910-0073	02660
A7U1	SCR 2N4167	2108-0004	04713
A7U2	IC REG +5V LM323	2118-0091	27014
A7C1	CAP ELECT 6.8 UF 35V	0403-0052	74840

BOTTOM PRINTED CIRCUIT BOARD ASSEMBLY

REF DES	DESCRIPTION	PART NUMBER	MFC
C001	CAP 220PF 100V	0418-0064	00853
C002			
C003	CAP 220PF 100V	0418-0064	00853
C004	CAP CER .01UF 50V	0418-0014	97418
C005	CAP CER .01UF 50V	0418-0014	97418
C006	CAP 30PF 100V	0415-0086	00853
C007	CAP 10PF 100V M	0415-0009	00853
C008	CAP 10PF 100V M	0415-0009	00853
C009	CAP CER .01UF 50V	0418-0014	97418
C010	CAP CER .01UF 50V	0418-0014	97418
C011	CAP ELECT 6.8UF 35V	0403-0052	74840
C012	CAP ELECT 6.8UF 35V	0403-0052	74840
C013	CAP ELECT 6.8UF 35V	0403-0052	74840
C014	CAP 220PF 100V	0418-0064	00853
C015	CAP CER .01UF 50V	0418-0014	97418
C016	CAP 10PF 100V M	0415-0009	00853
C017	CAP CER .01UF 500V	0418-0014	97418
C018			
C019			
C020	CAP 220PF 100V	0418-0064	00853
C021			
C022	CAP CER .01UF 50V	0418-0014	97418
C023	CAP ELECT 6.8UF 35V	0403-0052	74840
C024	CAP ELECT 6.8UF 35V	0403-0052	74840
C025			
C026	CAP CER .01UF 50V	0418-0014	97418
C027	CAP 100PF MICA	0415-0059	00853
C028	CAP CER .01UF 50V	0418-0014	97418
C029	CAP CER .01UF 50V	0418-0014	97418
C030	CAP ELECT 6.8UF 35V	0403-0052	74840
C031	CAP ELECT 6.8UF 35V	0403-0052	74840
C032			
C033	CAP ELECT 6.8UF 35V	0403-0052	74840
C034	CAP CER .01UF 50V	0418-0014	97418
C035	CAP CER .01UF 50V	0418-0014	97418
C036	CAP 30PF 100V	0415-0086	00853
C037	CAP 30PF 100V	0415-0086	00853
C038	CAP 30PF 100V	0415-0086	00853
C039	CAP 220PF 100V	0418-0064	00853
C040	CAP CER .01UF 50V	0418-0014	97418
C041	CAP CER .1UF 50V	0418-0008	96045
C042	CAP CER .01UF 50V	0418-0014	97418
C043	CAP CER .1UF 50V	0418-0008	96045
C044	CAP CER .01UF 50V	0418-0014	97418
C045	CAP ELECT 6.8UF 35V	0403-0052	74840
C046	CAP ELECT 6.8UF 35V	0403-0052	74840
C047	CAP CER .01UF 50V	0418-0014	97418
C048	CAP ELECT 6.8UF 35V	0403-0052	74840
C049	CAP 22UF 16V ELECT	0401-0014	56289
C050	CAP ELECT 6.8UF 35V	0403-0052	74840
C051	CAP .001UF 50V	0418-0016	97418
C052	CAP .001UF 50V	0418-0016	97418
C053	CAP CER .01UF 50V	0418-0014	97418
C054	CAP CER .01UF 50V	0418-0014	97418
C055	CAP CER .01UF 50V	0418-0014	97418

C056	CAP 470PF 50V	0415-0117	00853
C057	CAP 68PF	0415-0027	00853
C058	CAP 220PF 100V	0418-0064	00853
C059	CAP ELECT 6.8UF 35V	0403-0052	74840
C060	CAP MICA 15PF 500V	0415-0080	00853
C061	CAP 22PF 100V	0415-0083	00853
C062			
C063 (A,B,C,D,E)	CAP SET 910PF DET	0425-0003HN	34511
C064	CAP ELECT 6.8UF 35V	0403-0052	74840
C065	CAP VAR 8-50PF	0423-0004	90201
C066	CAP ELECT 6.8UF 35V	0403-0052	74840
C067	CAP CER .1UF 50V	0418-0008	96045
C068	CAP ELECT 6.8UF 35V	0403-0052	74840
C069	CAP CER .01UF 50V	0418-0014	97418
C070	CAP 47PF	0415-0091	00853
C071	CAP MICA 15PF 500V	0415-0080	00853
C072	CAP 180PF	0418-0063	00853
C073 (A,B,C,D,E)	CAP SET 910PF DET	0425-0003HN	34511
C074	CAP 22PF 100V	0415-0083	00853
C075	CAP VAR 8-50PF	0423-0004	90201
C076	CA 47PF	0415-0091	00853
C077	CAP 220PF 100V	0418-0064	00853
C078	CAP CER .1UF 50V	0418-0008	96045
C079	CAP CER .01UF 50V	0418-0014	97418
C080	CAP CER .01UF 50V	0418-0014	97418
C081			
C082			
C083	CAP VAR 3-12PF	0423-0005	90201
C084	CAP .001UF 50V	0418-0016	97418
C085	CAP .001UF 50V	0418-0016	97418
C086	CAP ELECT 6.8UF 35V	0403-0052	74840
C087			
C088	CAP ELECT 6.8UF 35V	0403-0052	74840
C089	CAP CER .01UF 50V	0418-0014	97418
C090	CAP 10PF 100V M	0415-0009	00853
C091	CAP ELECT 6.8UF 35V	0403-0052	74840
C092			
C093	CAP CER .01UF 50V	0418-0014	97418
C094	CAP 220PF 100V	0418-0064	00853
C095	CAP 220PF 100V	0418-0064	00853
C096	CAP ELECT 6.8UF 35V	0403-0052	74840
C097			
C098	CAP ELECT 6.8UF 35V	0403-0052	74840
C099	CAP CER .01UF 50V	0418-0014	97418
C100	CAP .001UF 50V CERA	0418-0016	97418
C101	CAP .047 50V CERA	0418-0015	96095
C102	CAP 22UF 16V ELECT	0401-0014	56289
C103	CAP .001UF 50V CERA	0418-0016	97418
C104	CAP CER .01UF 50V	0418-0014	97418
C105	CAP .001UF 50V	0418-0016	97418
C106	CAP ELECT 6.8UF 35V	0403-0052	74840
C107	CAP .001UF 50V CERA	0418-0016	97418
C108	CAP .001UF 50V CERA	0418-0016	97418
C109	CAP .047 50V CERA	0418-0015	96095
C110	CAP ELECT 6.8UF 35V	0403-0052	74840
C111	CAP .047 50V CERA	0418-0015	96095
C112			

C113	CAP .001UF 50V CERA	0418-0016	97418
C114	CAP CER .01UF 50V	0418-0014	97418
C115	CAP 22UF 16V ELECT	0401-0014	56289
C116	CAP 10,000UF 15V ELECT	0403-0021	56289
C117			
C118	CAP 2200UF 35V ELECT	0403-0055	56289
C119	CAP 2200UF 35V ELECT	0403-0055	56289
C120	CAP 22PF 100V	0415-0083	00853
C121	CAP CER .01UF 50V	0418-0014	97418
C122	CAP CER .01UF 50V	0418-0014	97418
C123	CAP CER .01UF 50V	0418-0014	97418
C124	CAP CER .01UF 50V	0418-0014	97418
C125	CAP 22PF 100V	0415-0083	00853
C126	CAP ELECT 6.8UF 35V	0403-0052	74840
C127			
C128	CAP .001UF 50V	0418-0016	97418
C129	CAP ELECT 6.8UF 35V	0403-0052	74840
C130	CAP ELECT 6.8UF 35V	0403-0052	74840
C131	CAP .001UF 50V	0418-0016	97418
C132			
C133	CAP .001UF 50V CERA	0418-0016	97418
C134	CAP .047 50V CERA	0418-0015	96095
C135	CAP .047 50V CERA	0418-0015	96095
C136	CAP ELECT 6.8UF 35V	0403-0052	74840
C137			
C138	CAP .001UF 50V	0418-0016	97418
C139	CAP .047 50V CERA	0418-0015	96095
C140	CAP CER .01UF 50V	0418-0014	97418
C141	CAP.001UF 50V	0418-0016	97418
C142	CAP ELECT 6.8UF 35V	0403-0052	74840
C143	CAP 1000UF 63V ELECT	0403-0047	74840
C144	CAP 1000UF 63V ELECT	0403-0047	74840
C145	CAP SET 910PF	0425-0003HN	34511
C146	CAP SET 910PF	0425-0003HN	34511
C147			
C148	CAP SET 910PF	0425-0003HN	34511
C149	CAP SET 910PF	0425-0003HN	34511
C150	SEL		34511
C151	CAP SET 910PF	0425-0003HN	
C152			
C153	CAP CER .01UF 50V	0418-0014	97418
C154	CAP CER .01UF 50V	0418-0014	97418
C155	CAP .001UF 50V CERA	0418-0016	97418
C156	CAP ELECT 6.8UF 35V	0403-0052	74840
C157			
C158	CAP CER .01UF 50V	0418-0014	97418
C159	CAP CER .01UF 50V	0418-0014	97418
C160	CAP ELECT 6.8UF 35V	0403-0052	74840
C161	CAP ELECT 6.8UF 35V	0403-0052	74840
C162			
C163	CAP .001UF 50V CERA	0418-0016	97418
C164	CAP .001UF 50V CERA	0418-0016	97418
C165	CAP 68PF	0415-0027	00853
C166	CAP CER .01UF 50V	0418-0014	97418
C167			
C168	CAP CER .01UF 50V	0418-0014	97418
C169	CAP CER .01UF 50V	0418-0014	97418
C170	CAP VAR 8-50PF	0423-0004	90201

C171	CAP .001UF 50V CERA	0418-0016	97418
C172			
C173	CAP 47PF	0415-0091	00853
C174	CAP ELECT 6.8UF 35V	0403-0052	74840
C175	CAP CER .01UF 50V	0418-0014	97418
C176	CAP VAR 8-50PF	0423-0004	90201
C177	CAP ELECT 100UF .25V	0403-0014	56289
C178	CAP 47PF	0415-0091	00853
C179	CAP ELECT 6.8UF 35V	0403-0052	74840
C180	CAP ELECT 6.8UF 35V	0403-0052	74840
C181	CAP .001UF 50V CERA	0418-0016	97418
C182			
C183	CAP .001UF 50V CERA	0418-0016	97418
C184	CAP 47PF	0415-0091	00853
C185	CAP CER .01UF 50V	0418-0014	97418
C186	CAP 100PF MICA	0415-0059	00853
C187			
C188	CAP 68PF	0415-0027	00853
C189			
C190			
D001	DIODE 1N751	2102-0021	04713
D002			
D003	DIODE 1N4005	2101-0005T	07263
D004	DIODE 1N4005	2101-0005T	07263
D005	DIODE 1N4005	2101-0005T	07263
D006	DIODE 1N4005	2101-0005T	07263
D007			
D008	DIODE 1N4005	2101-0005T	07263
D009	DIODE 1N4005	2101-0005T	07263
D010	DIODE IN4005	2101-0005T	07263
D011	DIODE 1N4005	2101-0005T	07263
D012			
D013			
D014	DIODE 1N914	2101-0010	07263
D015	DIODE 1N914	2101-0010	07263
D016	DIODE 1N914	2101-0010	07263
D017			
D018	DIODE 1N914	2101-0010	07263
D019	DIODE 1N4001	2101-0002	07263
D020	DIODE 1N4001	2101-0002	07263
D021	DIODE 1N4001	2101-0002	07263
D022			
D023	DIODE 1N753	2102-0023	04713
D024	DIODE 1N4001	2101-0002	07263
D025	DIODE IN4001	2101-0002	07263
D026	DIODE IN751	2102-0021	04713
D027			
D028	DIODE 1N751	2102-0021	04713
D029	DIODE 1N751	2102-0021	04713
D030	DIODE 1N751	2102-0021	04713
D031	DIODE 1N963	2101-0022	04713
D032	DIODE 1N4001	2101-0002	07263
D033	DIODE 1N753	2102-0023	04713
D034	DIODE 1N914	2101-0010	07263
D035	DIODE 1N914	2101-0010	07263
D036	DIODE 1N914	2101-0010	07263
D037			
D038	DIODE 1N914	2101-0010	07263

D039	DIODE 1N914	2101-0010	07263
D040	DIODE 1N914	2101-0010	07263
D041	DIODE 1N914	2101-0010	07263
D042			
D043	DIODE 1N914	2101-0010	07263
D044	DIODE 1N914	2101-0010	07263
D045	DIODE 1N914	2101-0010	07263
D046	DIODE 1N914	2101-0010	07263
D047			
D048	DIODE 1N914	2101-0010	07263
D049	DIODE 1N914	2101-0010	07263
D050	DIODE 1N914	2101-0010	07263
D051	DIODE 1N914	2101-0010	07263
D052			
D053	DIODE 1N914	2101-0010	07263
D054	DIODE 1N914	2101-0010	07263
D055	DIODE 1N914	2101-0010	07263
D056	DIODE 1N914	2101-0010	07263
D057	DIODE 1N914	2101-0010	07263
D058	DIODE 5082-2811	2101-0023	28480
D059	DIODE 1N751	2102-0021	04713
D060	DIODE 5082-2811	2101-0023	28480
D061	DIODE 5082-2811	2101-0023	28480
D062	DIODE 1N751	2102-0021	04713
D063	DIODE 1N5227	2102-0014	04713
D064	DIODE 1N753	2102-0023	04713
D065	DIODE 1N753	2102-0023	04713
D066	DIODE IN753	2102-0023	04713
D067 (A & B)	MATCHED (2) IN751	2104-0006HN	34511
D068	DIODE 1N753	2102-0023	04713
D069	DIODE 1N914	2101-0010	07263
D070	DIODE 1N914	2101-0010	07263
D071	DIODE 1N914	2101-0010	07263
D072			
D073	DIODE 1N914	2101-0010	07263
D074	DIODE 1N914	2101-0010	07263
D075	DIODE 1N914	2101-0010	07263
D076	DIODE 1N914	2101-0010	07263
D077			
D078	DIODE 1N914	2101-0010	07263
D079	DIODE 1N914	2101-0010	07263
D080	DIODE 1N914	2101-0010	07263
D081	DIODE 1N914	2101-0010	07263
D082			
D083	DIODE 1N753	2102-0023	04713
D084	DIODE 1N753	2102-0023	04713
D085	DIODE 1N753	2102-0023	04713
D086	DIODE 1N753	2102-0023	04713
D087			
D088	DIODE 1N914	2101-0010	07263
D089	DIODE 1N914	2101-0010	07263
D090	DIODE 1N914	2101-0010	07263
D091	DIODE 1N914	2101-0010	07263
D092	DIODE 1N914	2101-0010	07263
D093	DIODE 1N4005	2101-0005T	07263
D094	DIODE 1N4005	2101-0005T	07263
D095	DIODE 1N4005	2101-0005T	07263
D096	DIODE 1N4005	2101-0005T	07263

D097	DIODE 1N914	2101-0010	07263
D098	DIODE 1N5246	2102-0032	04713
D099	DIODE 1N5246	2102-0032	04713
F001	FUSE 1/16 AP	1005-0099	75915
F002			
F003	FUSE 1/16 AP	1005-0099	75915
F004	FUSE 1/16 AP	1005-0099	75915
F005	FUSE 1/16 AP	1005-0099	75915
F006	FUSE 6.25A 3AG	1005-0055	75915
F007	FUSE 1/2 AP	1005-0103	75915
F008	FUSE 1/2 AP	1005-0103	75915
J001	HEADER RT ANGLE 40 PIN	2710-0123	75037
J002	HEADER 8 PIN	2710-0012	27264
J003	PC CONN 2 PIN	2710-0007T	27264
J004	HEADER RT ANGLE 20 PIN	2710-0124	75037
J005	PC CONN 2 PIN	2710-0007T	27264
J006	PC CONN 4 PIN	2710-0009MT	27264
J007	PC CONN 4 PIN MODIFIED	2710-0009MT	27264
J008	PC CONN 6 PIN	2710-0011	27264
J009	PC CONN 4 PIN	2710-0009MT	27264
J010	PC CONN 6 PIN	2710-0011	27264
J011	PC CONN 4 PIN	2710-0009MT	27264
J012	PC CONN 2 PIN	2710-0007T	27264
J013	HEADER RT ANGLE 20 PIN	2710-0124	75037
J014	PC CONN 2 PIN	2710-0007T	27264
J015	HEADER RT ANGLE 20 PIN	2710-0124	75037
J016	PC CONN 2 PIN	2710-0007T	27264
J017	PC CONN 2 PIN	2710-0007T	27264
J018			
J019			
J020			
K001	RELAY SPST	2560-0006	88330
K002			
K003	RELAY SPST	2560-0006	88330
K004	RELAY SPST	2560-0006	88330
K005	RELAY SPST	2560-0006	88330
K006	RELAY SPST	2560-0006	88330
K007			
K008	RELAY SPST	2560-0006	88330
K009	RELAY SPST	2560-0006	88330
K010	RELAY SPST	2560-0006	88330
K011	RELAY SPST	2560-0006	88330
K012			
K013	RELAY SPST	2560-0006	88330
K014	RELAY SPST	2560-0006	88330
K015	RELAY SPST	2560-0006	88330
K016	RELAY SPST	2560-0006	88330
K017			
K018	RELAY SPST	2560-0006	88330
K019	RELAY SPST	2560-0006	88330
K020	RELAY SPST	2560-0006	88330
K021	RELAY SPST	2560-0006	88330
K022	RELAY SPST	2560-0006	88330
K023	RELAY SPST	2560-0006	88330
K024	RELAY SPST	2560-0006	88330
K025	RELAY SPST	2560-0006	88330

K026	RELAY SPST	2560-0006	88330
K027	RELAY SPST	2560-0006	88330
L001			
L002	BEAD	1238-0008	01121
L003	BEAD	1238-0008	01121
L004			
L005			
L006	BEAD	1238-0008	01121
L007			
L008	BEAD	1238-0008	01121
L009	BEAD	1238-0008	01121
L010	BEAD	1238-0008	01121
L011	BEAD	1238-0008	01121
L012			
L013	BEAD	1238-0008	01121
L014	BEAD	1238-0008	01121
L015			
L016			
L017			
L018	BEAD	1238-0008	01121
L019	BEAD	1238-0008	01121
L020	BEAD	1238-0008	01121
L021	CHOKE .47UH	1214-0051	99848
L22 & 23	BEAD	1238-0008	01121
Q001	TRANS 2N4258	2112-0025M	27014
Q002			
Q003	TRANS 2N4258	2112-0025M	27014
Q004	TRANS 2N4258	2112-0025M	27014
Q005	TRANS 2N4258	2112-0025M	27014
Q006	TRANS 2N4258	2112-0025M	27014
Q007			
Q008	TRANS PNP 2N4403	2112-0005	27014
Q009	TRANS 2N4258	2112-0025M	27014
Q010	TRANS 2N3563	2111-0023M	27014
Q011	TRANS 2N4258	2112-0025M	27014
Q012			
Q013	TRANS 2N4258	2112-0025M	27014
Q014	TRANS 2N4258	2112-0025M	27014
Q015	TRANS 2N4258	2112-0025M	27014
Q016	TRANS 2N4258	2112-0025M	27014
Q017			
Q018	TRANS 2N4258	2112-0025M	27014
Q019	TRANS 2N4258	2112-0025M	27014
Q020	TRANS 2N4258	2112-0025M	27014
Q021	TRANS 2N4258	2112-0025M	27014
Q022			
Q023	TRANS 2N4258	2112-0025M	27014
Q024	TRANS 2N4258	2112-0025M	27014
Q025	TRANS 2N3563	2111-0023M	27014
Q026	TRANS 2N3563	2111-0023M	27014
Q027			
Q028	TRANS 2N4258	2112-0025M	27014
Q029	TRANS 2N4258	2112-0025M	27014
Q030	TRANS 2N3563	2111-0023M	27014
Q031	TRANS MPS3646	2111-0005	27014
Q032			
Q033	TRANS 2N4258	2112-0025M	27014
Q034	TRANS 2N4258	2112-0025M	27014

Q035			
Q036			
Q037			
Q038	TRANS 2N4258	2112-0025M	27014
Q039 (A & B)	TRANS M(2) 2N4258	2115-0008HN	27014
Q040			
Q041	TRANS MPS6544	2111-0035	27014
Q042			
Q043 (A & B)	TRANS M(2) 2N4258	2115-0008HN	27014
Q044			
Q045	TRANS MPS6544	2111-0035	27014
Q046	TRANS 2N3563	2111-0023M	27014
Q047			
Q048	TRANS 2N3563	2111-0023M	27014
Q049	TRANS 2N4258	2112-0025M	27014
Q050	TRANS 2N4258	2112-0025M	27014
Q051	TRANS 2N4250	2112-0023	27014
Q052			
Q053	TRANS 2N4250	2112-0023	27014
Q054	TRANS 2N5462	2114-0011	27014
Q055	TRANS 2N4258	2112-0025M	27014
Q056	TRANS 2N5160	2112-0027	27014
Q057			
Q058	TRANS MPS6544	2111-0035	27014
Q059	TRANS 2N3866	2111-0026	27014
Q060	TRANS NPN2N2484	2111-0021	27014
Q061	TRANS 2N4250	2112-0023	27014
Q062			
Q063	TRANS NPN2N2484	2111-0021	27014
Q064	TRANS 2N4250	2112-0023	27014
Q065	TRANS 2N4250	2112-0023	27014
Q066	TRANS 2N4250	2112-0023	27014
Q067			
Q068	TRANS 2N4250	2112-0023	27014
Q069	TRANS 2N4250	2112-0023	27014
Q070	TRANS 2N4250	2112-0023	27014
Q071	TRANS 2N4250	2112-0023	27014
Q072			
Q073	TRANS 2N4250	2112-0023	27014
Q074	TRANS 2N4250	2112-0023	27014
Q075	TRANS 2N4250	2112-0023	27014
Q076	TRANS 2N4258	2112-0025M	27014
Q077			
Q078	TRANS 2N4258	2112-0025M	27014
Q079	TRANS 2N4258	2112-0025M	27014
Q080	TRANS MPS3646	2111-0005	27014
Q081	TRANS MPS3646	2111-0005	27014
Q082	TRANS 2N3866	2111-0026	27014
Q083	TRANS 2N4121	2112-0022	27014
Q084	TRANS 2N5160	2112-0027	27014
Q085	TRANS MPS3646	2111-0005	27014
Q086	TRANS 2N3563	2111-0023M	27014
Q087			
Q088	TRANS 2N4258	2112-0025M	27014
Q089 (A & B)	TRANS M(2) 2N4258	2115-0008HN	27014
Q090	TRANS 2N4258	2112-0025M	27014

Q091	TRANS 2N3563	2111-0023M	27014
Q092			
Q093	TRANS 2N3563	2111-0023M	27014
Q094	TRANS 2N4258	2112-0025M	27014
Q095	TRANS 2N4258	2112-0025M	27014
Q096	TRANS 2N4258	2112-0025M	27014
Q097			
Q098 (A & B)	TRANS M(2) 2N3563	2115-0004HN	27014
Q099 (A & B)	TRANS M(2) 2N3563	2115-0004HN	27014
Q100 (A & B)	TRANS M(2) 2N3563	2115-0004HN	27014
Q101	FET P-CH 2N5485	2114-0023	27014
Q102			
Q103	TRANS MPS3646	2111-0005	27014
Q104	TRANS MPS6544	2111-0035	27014
Q105 (A & B)	TRANS M(2) 2N5179	2115-0013HN	27014
Q106	TRANS MPS6544	2111-0035	27014
Q107			
Q108	TRANS 2N4258	2112-0025M	27014
Q109	TRANS 2N4258	2112-0025M	27014
Q110 (A & B)	TRANS M(2) 2N4258	2115-0008HN	27014
Q111 (A & B)	TRANS M(2) 2N4258	2115-0008HN	27014
Q112			
Q113 (A & B)	TRANS M(2) 2N4258	2115-0008HN	27014
Q114	TRANS MJE2955	2112-0020	27014
Q115	TRANS MJE3055	2111-0022	27014
R001	RES 1K 5% 1/4W	0300-1103T	01121
R002	RES 100 5% 1/4W	0300-1102	01121
R003	RES 1K 5% 1/4W	0300-1103T	01121
R004	RES 100 5% 1/4W	0300-1102	01121
R005	RES 100 5% 1/4W	0300-1102	01121
R006	RES 100 5% 1/4W	0300-1102	01121
R007	RES 100 5% 1/4W	0300-1102	01121
R008	RES 100 5% 1/4W	0300-1102	01121
R009	RES CF 680 OHM 5% 1/4W	0300-1682T	01120
R010	RES 220 5% 1/4W	0300-1222	01121
R011	RES 10 5% 1/4W	0300-1101	01121
R012			
R013	RES 10 5% 1/4W	0300-1101	01121
R014	RES 10 5% 1/4W	0300-1101	01121
R015	RES CF 620 OHM 5% 1/4W	0300-1622	01121
R016	RES 1.8K 5% 1/4W	0300-1183	01121
R017			
R018	RES 3.3K 5% 1/4W	0300-1333T	01121
R019	RES 150 5% 1/4W	0300-1152	01121
R020	RES 100 5% 1/4W	0300-1102	01121
R021	RES 100 5% 1/4W	0300 1102	01121
R022	RES CF 1K 5% 1/4W	0300-1153	01121
R023	RES 5% 1/4W 150	0300-1152	01121
R024	RES 430 5% 1/4W 390	0300-1392	01121
R025	RES CF 1K 5% 1/4W	0300-1103T	01121
R026	RES CF 1K 5% 1/4W	0300-1103T	01121

R027	RES 1/4W 5% 330 OHM	0300-1332	01121
R028	RES CF 1K 5% 1/4W	0300-1103T	01121
R029	RES 1.8K 5% 1/4W	0300-1183	01121
R030	RES 3.3K 5% 1/4W	0300-1333T	01121
R031	RES MF 6.04K 1% 1/8W	0307-1763	07115
R032			
R033	RES CF 620 OHM 5% 1/4W	0300-1622	01121
R034	RES 143 1% 1/8W	0307-1162	07115
R035	RES 162K 1% 1/8MF	0307-1215	07115
R036	RES 143 1% 1/8W	0307-1162	07115
R037			
R038	RES 143 1% 1/8W	0307-1162	07115
R039	RES 4.7K 5% 1/4W	0300-1473	01121
R040	RES 100 5% 1/4W	0300-1102	01121
R041	RES MF 10K 1% 1/8W	0307-1014M	07115
R042	RES MF 3.01K 1% 1/8W	0307-1473	07115
R043	RES 100K 1% 1/8W	0307-1015	07115
R044	RES MF 10K 1% 1/8W	0307-1014M	07115
R045	RES MF 20K 1% 1/8W	0307-1304	07115
R046	RES MF 10K 1% 1/8W	0307-1014M	07115
R047			
R048	RES 5.6M 5% 1/4W	0300-1566	01121
R049	RES 100K 1% 1/8W	0307-1015	07115
R050	RES 75K 1% 1/8W	0307-1854	07115
R051	RES 61.9K 1% 1/8W	0307-1774	07115
R052			
R053	RES 1.74K 1% 1/8W	0307-1243	07115
R054			
R055	RES 3.24K 1% 1/8W	0307-1503	07115
R056	RES 11.8K 1% 1/8W	0307-1084	07115
R057			
R058	RES CF 10K 5% 1/4W	0300-1104T	01121
R059	RES CF 10K 5% 1/4W	0300-1104T	01121
R060	RES 243 OHM 1% 1/8W	0307-1382	07115
R061	RES 2.43K 1% 1/8W	0307-1383	07115
R062			
R063	RES 500 VAR CERMET	0326-0168	32977
R064 (A & B)	RES M(2) 10K 1% 1/8W	0316-0102H	07115
R065	RES 100 5% 1/4W	0300-1102	01121
R066	RES 1/4W 5% 330 OHM	0300-1332	01121
R067	RES 100 5% 1/4W	0300-1102	01121
R068	RES 1K 5% 1/4W	0300-1103T	01121
R069	RES 100 5% 1/4W	0300-1102	01121
R070	RES 100 5% 1/4W	0300-1102	01121
R071	RES 150 5% 1/4W	0300-1152	01121
R072	RES 2.7K 5% 1/4W	0300-1273	01121
R073	RES 150 5% 1/4W	0300-1152	01121
R074	RES 560 5% 1/4W	0300-1562	01121
R075	RES 1K 5% 1/4W	0300-1103T	01121
R076	RES 100 5% 1/4W	0300-1102	01121
R077	RES CF 680 OHM 5% 1/4W	0300-1682T	01120
R078	RES MF 2K 1% 1/8W	0307-1303	07115
R079	RES 118 1% 1/8W	0307-1082	07115
R080	RES 100 5% 1/4W	0300-1102	01121
R081	RES MF 2K 1% 1/8W	0307-1303	07115
R082			
R083	RES 118 1% 1/8W	0307-1082	07115
R084	RES 100 5% 1/4W	0300-1102	01121

R085	RES 100 5% 1/4W	0300-1102	01121
R086	RES 825 1% 1/4W	0307-1892	07115
R087			
R088			
R089			
R090	RES 332 1% 1/8W	0307-1512	07115
R091	RES 100 1% 1/8W	0307-1012	07115
R092			
R093	RES 665 5% 1/4W	0307-1802	01120
R094	RES 5.6K 5% 1/4W	0300-1563	01120
R095	RES 3.3K 5% 1/4W	0300-1333T	01121
R096	RES 2.2K 5% 1/4W	0300-1223	01120
R097			
R098	RES 4.3M 5% 1/4W	0300-1436	01120
R099	RES 1.3K 5% 1/4W	0300-1133	01120
R100	RES 4.3M 5% 1/4W	0300-1436	01120
R101			
R102			
R103	RES CF 100K 5% 1/4W	0300-1105T	01121
R104	RES CF 470 OHM 5% 1/4W	0300-1472T	01121
R105	RES 100 5% 1/4W	0300-1102	01121
R106	RES 100 5% 1/4W	0300-1102	01121
R107			
R108	RES 200 5% 1/4W	0300-1202	01121
R109	RES 1/4W 5% 330 OHM	0300-1332	01121
R110	RES 200 5% 1/4W	0300-1202	01121
R111	RES 1.3K 5% 1/4W	0300-1133	01120
R112			
R113	RES 560 5% 1/4W	0300-1562	01121
R114	RES 100 5% 1/4W	0300-1102	01121
R115	RES CF 1K 5% 1/4W	0300-1103T	01121
R116	RES 100 5% 1/4W	0300-1102	01121
R117			
R118	RES 100 5% 1/4W	0300-1102	01121
R119	RES 100 5% 1/4W	0300-1102	01121
R120	RES CF 1K 5% 1/4W	0300-1103T	01121
R121	RES 243 1% 1/4W	0308-1382	01121
R122			
R123	RES 1.62K 1% 1/4W	0307-1213	07115
R124	RES 120 5% 1/4W	0300-1122	01121
R125	RES 47 5% 1/4W	0300-1471	01121
R126	RES 24.3 1% 1/8	0307-1381	07115
R127			
R128	RES 47 5% 1/4W	0300-1471	01121
R129	RES 243 1% 1/4W	0308-1382	01121
R130	RES 174 1% 1/8W	0307-1242	07115
R131	RES 100 1% 1/8W	0307-1012	07115
R132			
R133	RES 24.3 1% 1/8	0307-1381	07115
R134	RES 47 5% 1/4W	0300-1471	01121
R135	RES 1.62K 1% 1/4W	0307-1213	07115
R136	RES 120 5% 1/4W	0300-1122	01121
R137			
R138	RES 174 1% 1/8W	0307-1242	07115
R139	RES 100 1% 1/8W	0307-1012	07115
R140	RES 4.7K 5% 1/4W	0300-1473	01121
R141	RES 300 5% 1/4W	0300-1302	01121
R142	RES 100 1% 1/8W	0307-1012	07115
R143	RES 100 5% 1/4W	0300-1102	01121

R144	RES MF 11K 1% 1/8W	0307-1054	07115
R145	RES 100 5% 1/4W	0300-1102	01121
R146	RES 3.92K 1% 1/8W	0307-1583	07115
R147			
R148	RES 402 1% 1/8W	0307-1592	07115
R149	RES 487 1% 1/8W	0307-1672	07115
R150	RES 1.87K 1% 1/8W	0307-1273	07115
R151	RES 4.7K 5% 1/4W	0300-1473	01121
R152	RES 100 1% 1/8W	0307-1012	07115
R153	RES 100 5% 1/4W	0300-1102	01121
R154	RES 10K VAR CERMET	0326-0171	32977
R155	RES 7.5K 1% 1/8W	0307-1853	07115
R156	RES MF 4.02K 1% 1/8W	0307-1593	07115
R157			
R158	RES MF 4.02K 1% 1/8W	0307-1593	07115
R159			
R160			
R161			
R162			
R163			
R164	RES 100 5% 1/4W	0300-1102	01121
R165	RES MF 49.9 OHM 1% 1/8W	0307-1681	07115
R166	RES MF 49.9 OHM 1% 1/8W	0307-1681	07115
R167			
R168	RES 100 1% 1/8W	0307-1012	07115
R169	RES 100 1% 1/8W	0307-1012	07115
R170	RES 100 1% 1/8W	0307-1012	07115
R171	RES 82.5 1% 1/8W	0307-1891	07115
R172	RES 9.1M 5% 1/4W	0300-1916	01121
R173	RES 100 1% 1/8W	0307-1012	07115
R174	RES 294 1% 1/8W	0307-1462	07115
R175			
R176	RES 787 1% 1/8W	0307-1872	07115
R177	RES CF 330K 5% 1/4W	0300-1335	01121
R178	RES 100 VAR CERMET	0326-0167	32977
R179	RES 301 1% 1/8W	0307-1472	07115
R180	RES 301 1% 1/8W	0307-1472	07115
R181	RES 50 VAR CERMET	0326-0166	32977
R182	RES 93.1 1% 1/8W	0307-1941	07115
R183	SEL		
R184	RES 1.1K 1% 1/8W	0307-1053	07115
R185	RES 1.5K 1% 1/8W	0307-1183	07115
R186	RES MF 499 OHM 1% 1/8W	0307-1682	07115
R187	RES 2.2M 5% 1/4W	0300-1226	01121
R188	RES 619 1% 1/2W	0309-1772	07115
R189	RES MF 499 OHM 1% 1/8W	0307-1682	07115
R190	RES 3.65K 1% 1/8W	0307-1553T	07115
R191	RES CF 10K 5% 1/4W	0300-1104T	01121
R192			
R193			
R194	RES 1.82K 1% 1/8W	0307-1263	07115
R195	RES 1.69K 1% 1/8W	0307-1233	07115
R196	RES 7.5K 1% 1/8W	0307-1853	07115
R197			
R198	RES 909 1% 1/8W	0307-1932	07115
R199	RES MF 6.04K 1% 1/8W	0307-1763	07115
R200	RES 3.74K 1% 1/8W	0307-1563	07115
R201	RES 4.7K 5% 1/4W	0300-1473	01121
R202			

R203	RES CF 470 OHM 5% 1/4W	0300-1472T	01121
R204	RES CF 680 OHM 5% 1/4W	0300-1682T	01120
R205	RES 100 5% 1/4W	0300-1102	01121
R206	RES 130 5% 1/4W	0300-1132	01121
R207			
R208	RES 130 5% 1/4W	0300-1132	01121
R209	RES 82 5% 1/4W	0300-1821	01121
R210	RES 24K 5% 1/4W	0300-1244T	01121
R211	RES 47K 5% 1/4W	0300-1474T	01121
R212			
R213	RES 1.5K 5% 1/4W	0300-1153	01121
R214	RES 1K 5% 1/4W	0300-1103T	01121
R215	RES 22K 5% 1/4W	0300-1224	01121
R216	RES 160 5% 1/4W	0300-1162	01121
R217			
R218	RES 100 5% 1/4W	0300-1102	01121
R219	RES 270 5% 1/4W	0300-1272	01121
R220	RES CF 10K 5% 1/4W	0300-1104T	01121
R221	RES 4.7K 5% 1/4W	0300-1473	01121
R222			
R223	RES 200 5% 1/4W	0300-1202	01121
R224	RES 15K 5% 1/4W	0300-1154	01121
R225	RES CF 1K 5% 1/4W	0300-1103T	01121
R226	RES 1K 5% 1/4W	0300-1103T	01121
R227			
R228	RES 1K 5% 1/4W	0300-1103T	01121
R229 (A,B & C)	RES M(3) 2.26K 1% 1/8W	0316-0106HN	07115
R230 (A,B & C)	RES M(3) 249 1% 1/8W	0316-0107HN	07115
R231	RES 4.7K 5% 1/4W	0300-1473	01121
R232			
R233	RES 100 5% 1/4W	0300-1102	01121
R234	RES MF 2K 1% 1/8W	0307-1303	07115
R235	RES 100 5% 1/4W	0300-1102	01121
R236	RES 1M 1% 1/8W	0307-1016	07115
R237			
R238	RES 4.7K 5% 1/4W	0300-1473	01121
R239	RES MF 10K 1% 1/8W	0307-1014M	07115
R240	RES 1.15K 1%	0307-1073	07115
R241	RES 100K 1% 1/8W	0307-1015	07115
R242	RES 200 VAR CERMET	0326-0177	32977
R243	RES 499K 1% 1/8W	0307-1685	07115
R244			
R245			
R246	RES CF 10K 5% 1/4W	0300-1104T	01121
R247			
R248	RES 40.2K 1% 1/8W	0307-1594	07115
R249	RES 40.2K 1% 1/8W	0307-1594	07115
R250	RES 47 5% 1/4W	0300-1471	01121
R251	RES 2.7K 5% 1/4W	0300-1273	01121
R252			
R253	RES 47 5% 1/4W	0300-1471	01121
R254	RES 47 5% 1/4W	0300-1471	01121
R255	RES MF 499 OHM 1% 1/8W	0307-1682	07115
R256	RES 10 5% 1/4W	0300-1101	01121
R257			
R258	RES 806 1% 1/8W	0307-1882	07115
R259	RES 27 5% 1/4W	0300-1271	01121

R260	RES 15 5% 1/2W	0301-1151	01121
R261	RES MF 499 OHM 1% 1/8W	0307-1682	07115
R262			
R263	RES 10 5% 1/4W	0300-1101	01121
R264	RES 10 5% 1/4W	0300-1101	01121
R265	RES MF 20K 1% 1/8W	0307-1304	07115
R266	RES 1K 5% 1/4W	0300-1103T	01121
R267			
R268	RES 1K 5% 1/4W	0300-1103T	01121
R269	RES 4.99K 1% 1/8W	0307-1683	07115
R270	RES 4.99K 1% 1/8W	0307-1683	07115
R271	RES 4.7K 5% 1/4W	0300-1473	01121
R272			
R273	RES 90.9K 1% 1/8W	0307-1934	07115
R274	RES 100 5% 1/4W	0300-1102	01121
R275	RES CF 10K 5% 1/4W	0300-1104T	01121
R276	RES CF 10K 5% 1/4W	0300-1104T	01121
R277			
R278	RES 20 5% 1/4W	0300-1201	01121
R279	RES 20 5% 1/4W	0300-1201	01121
R280	RES 4.7K 5% 1/4W	0300-1473	01121
R281	RES 100 5% 1/4W	0300-1102	01121
R282	RES 1.91K 1% 1/8W	0307-1283	07115
R283	RES 1M 1% 1/8W	0307-1016	07115
R284	RES 4.99K 1% 1/8W	0307-1683	07115
R285	RES MF 10K 1% 1/8W	0307-1014M	07115
R286	RES 100 5% 1/4W	0300-1102	01121
R287			
R288	RES 100 5% 1/4W	0300-1102	01121
R289	RES 4.7K 5% 1/4W	0300-1473	01121
R290	RES 187 1% 1/8W	0307-1272	07115
R291	RES MF 11K 1% 1/8W	0307-1054	07115
R292			
R293	RES 100 5% 1/4W	0300-1102	01121
R294	RES 3.92K 1% 1/8W	0307-1583	07115
R295	RES 1.4K 1% 1/8W	0307-1153	07115
R296	RES 200 5% 1/4W	0300-1202	01121
R297			
R298	RES 300 5% 1/4W	0300-1302	01121
R299	RES 4.7K 5% 1/4W	0300-1473	01121
R300	RES MF 3.01K 1% 1/8W	0307-1473	07115
R301	RES CF 10K 5% 1/4W	0300-1104T	01121
R302			
R303	RES 24.9K 1% 1/8W	0300-1394	07115
R304	RES 47 5% 1/4W	0300-1471	07115
R305	RES 1K 1% 1/4W	0308-1013	07115
R306	RES 68 5% 1/4W	0300-1681	01121
R307	RES MF 499 OHM 1% 1/8W	0307-1682	07115
R308	RES MF 7.68K 1% 1/8W	0307-1863	07115
R309	RES 10 5% 1/4W	0300-1101	01121
R310	RES CF 1K 5% 1/4W	0300-1103T	01121
R311	RES 806 1% 1/8W	0307-1882	07115
R312	RES 27 5% 1/4W	0300-1271	01121
R313	RES 7.15K 1% 1/8W	0307-1833	07115
R314			
R315	RES VAR 2K	0326-0170	32977
R316	RES 150 1% 1/2W	0309-1182	07115
R317	RES 68 5% 1/4W	0300-1681	01121
R318	RES 150 1% 1/2W	0309-1182	07115

R319	RES 150 1% 1/2W	0309-1182	07115
R320	RES 15 5% 1/2W	0301-1151	01121
R321	RES 2 5% 1/4W RN#	0300-1200	01121
R322			
R323	RES 15K 5% 1/4W	0300-1154	01121
R324	RES 15K 5% 1/4W	0300-1154	01121
R325	RES 15K 5% 1/4W	0300-1154	01121
R326	RES 15K 5% 1/4W	0300-1154	01121
R327			
R328	RES 10K 5% 1/4W	0300-1104T	01121
R329	RES CF 680 OHM 5% 1/4W	0300-1682T	01120
R330	RES 51 5% 1/4W	0300-1511	01121
R331	RES CF 680 OHM 5% 1/4W	0300-1682T	01120
R332			
R333	RES 100 5% 1/4W	0300-1102	01121
R334			
R335	RES 100 5% 1/4W	0300-1102	01121
R336	RES 3K 5% 1/4	0300-1303	01121
R337			
R338	RES 100 5% 1/4W	0300-1102	01121
R339	RES 270 5% 1/4W	0300-1272	01121
R340	RES 100 5% 1/4W	0300-1102	01121
R341	RES 100 5% 1/4W	0300-1102	01121
R342			
R343	RES 32.4 1% 1/8W	0307-1501	07115
R344	RES 32.4 1% 1/8W	0307-1501	07115
R345	RES 33 5% 1/4W	0300-1331	01121
R346	RES 200 5% 1/4W	0300-1202	01121
R347			
R348	RES 200 5% 1/4W	0300-1202	01121
R349	RES 130 5% 1/4W	0300-1132	01121
R350	RES 510 5% 1/4W	0300-1512	01121
R351	RES 510 5% 1/4W	0300-1512	01121
R352			
R353	RES 887 1% 1/8W	0307-1922	07115
R354	RES CF 1K 5% 1/4W	0300-1103T	01121
R355	RES 887 1% 1/8W	0307-1922	07115
R356	RES CF 2K 5% 1/4W	0300-1203	01121
R357			
R358	RES 100 5% 1/4W	0300-1102	01121
R359	RES 100 5% 1/4W	0300-1102	01121
R360	RES 100 5% 1/4W	0300-1102	01121
R361	RES CF 1K 5% 1/4W	0300-1103T	01121
R362	RES 100 5% 1/4W	0300-1102	01121
R363	RES 100 5% 1/4W	0300-1102	01121
R364	RES 4.7K 5% 1/4W	0300-1473	01121
R365	RES 100 5% 1/4W	0300-1102	01121
R366	RES 442 1% 1/8W	0307-1632	07115
R367			
R368	RES MF 11K 1% 1/8W	0307-1054	07115
R369	RES 3.92K 1% 1/8W	0307-1583	07115
R370	RES 10K VAR CERMET	0326-0171	32977
R371	RES MF 15K 1% 1/8W	0307-1184	07115
R372			
R373	RES 750 5% 1/4W	0300-1752	01121
R374	RES 39.2 1% 1/8W RN55D	0307-1581	07115
R375	RES 51 5% 1/4W	0300-1511	01121
R376	RES 39.2 1% 1/8W RN55D	0307-1781	07115
R377			

R378	RES 39.2 1% /18W RN55D	0307-1581	07115
R379	RES 100 5% 1/4W	0300-1102	01121
R380	RES 39.2 1% 1/8W RN55D	0307-1581	07115
R381	RES 5.11K 1% 1/8W	0307-1693	07115
R382			
R383	RES 1.21K 1% 1/8	0307-1093	07115
R384	RES 32.4 1% 1/8W	0307-1501	07115
R385	RES 51 5% 1/4W	0300-1511	01121
R386	RES 32.4 1% 1/8W	0307-1501	07115
R387			
R388	RES 100 5% 1/4W	0300-1102	01121
R389	RES 32.4 1% 1/8W	0307-1501	07115
R390	RES 1.82K 1% 1/8W	0307-1263	07115
R391	RES 32.4 1% 1/8W	0307-1501	07115
R392			
R393	RES 681 1% 1/4W RN60D	0308-1812	07115
R394	RES 51 5% 1/4W	0300-1511	01121
R395	RES 301 1% 1/8W	0307-1472	07115
R396	RES 37.4 1% 1/8W	0307-1561	07115
R397			
R398	RES 100 5% 1/4W	0300-1102	01121
R399	RES 37.4 1% 1/8W	0307-1561	07115
R400	RES 1.82K 1% 1/8W	0307-1263	07115
R401	RES 37.4 1% 1/8W	0307-1561	07115
R402			
R403	RES 562 1% 1/4W	0308-1732	07115
R404	RES 37.4 1% 1/8W	0307-1561	07115
R405	RES 34.8 1% 1 RN70D	0316-0033	07115
R406	RES 26.1 1% 1 RN70D	0316-0032	07115
R407			
R408	RES 41.2 1% 1 RN70D	0316-0034	07115
R409	RES 41.2 1% 1 RN70D	0316-0034	07115
R410	RES 41.2 1% 1 RN70D	0316-0034	07115
R411	RES 41.2 1% 1 RN70D	0316-0034	07115
R412			
R413	RES 51 5% 1/4W	0300-1511	01121
R414	RES 715 1% 1/8W	0307-1832	07115
R415	RES 100 5% 1/4W	0300-1102	01121
R416	RES MF 2K 1% 1/8W	0307-1303	07115
R417			
R418	RES MF 2K 1% 1/8W	0307-1303	07115
R419	RES 243 OHM 1% 1/8W	0307-1382	07115
R420	RES 10K VAR CERMET	0326-0171	32977
R421	RES 470 5% 1/2W	0301-1472	01121
R422	RES 100 1% 1/8W	0307-1012	07115
R423	RES MF 49.9 OHM 1% 1/8W	0307-1681	07115
R424	RES 100 1% 1/8W	0307-1012	07115
R425	RES MF 5.11K 1% 1/8W	0307-1693	07115
R426	RES 357 1% 1/8W RN#	0307-1542	07115
R427	RES 124 1% 1/8W RN#	0307-1102	07115
R428	RES 2.49K 1% 1/8W	0307-1393	07115
R429	RES 2.49K 1% 1/8W	0307-1393	07115
R430	RES 3.4K 1% 1/8W	0307-1523	07115
R431	RES 82.5 1% 1/8W RN#	0307-1891	07115
R432	RES 10 5% 1/4W	0300-1101	01121
R433	RES 100 VAR CERMET	0326-0167	32977
R434	RES 174 1% 1/8W	0307-1242	07115
R435	RES 750 5% 1/4W	0300-1752	01121
R436	RES 1.21K 1% 1/8	0307-1093	07115

R437	RES MF 5.11K 1% 1/8W	0307-1693	07115
R438	RES 5.11K 1% 1/8W	0307-1693	07115
R439	RES 100 5% 1/4W	0300-1102	01121
R440	RES 51 5% 1/4W	0300-1511	01121
R441	RES 681 1% 1/4W RN60D	0308-1812	07115
R442			
R443	RES 1.82K 1% 1/8W	0307-1263	07115
R444	RES 100 5% 1/4W	0300-1102	01121
R445	RES 51 5% 1/4W	0300-1511	01121
R446	RES 562 1% 1/4W	0308-1732	07115
R447	RES 562 1% 1/8W	0307-1732	07115
R448	RES 301 1% /18W	0307-1472	07115
R449	RES 100 5% 1/4W	0300-1102	01121
R450	RES 1.82K 1% 1/8W	0307-1263	07115
R451	RES 51 5% 1/4W	0300-1511	01121
R452			
R453	RES 57.6 1% 1/8W RN#	0307-1741	07115
R454	RES 26.1 1% 1 RN70D	0316-0032	07115
R455	RES 390 5% 1/4W	0300-1392	01121
R456	RES 2K 5% 1/4W RN#	0300-1203	01121
R457			
R458	RES 348 1% 1/8W	0307-1532	07115
R459	RES VAR 2K	0326-0170	32977
R460			
R461	RES 68 5% 1/4W	0300-1681	01121
R462			
R463	RES 56.2 1% 1/8W	0308-1731	07115
R464	RES 11.3 1% 1/4W	0308-1061	07115
R465	RES 100 VAR CERMET	0326-0167	32977
R466	RES 200 5% 1/4W	0300-1202	01121
R467			
R468	RES 1/4W 5% 330 OHM	0300-1332	01121
R469	RES 200 5% 1/4W	0300-1202	01121
R470	RES 56.2 1% 1/8W	0308-1731	07115
R471	RES 3.9K 5% 1/4W	0300-1393	01121
R472			
R473	RES 11.3 1% 1/4W	0308-1061	07115
R474	RES 3.9K 5% 1/4W	0300-1393	01121
R475	RES 100 VAR CERMET	0326-0167	32977
RN01	RES 680 NTWK SIP	0317-0011	32977
RN02			
RN03	RES 680 NTWK SIP	0317-0011	32977
RN04	1.8K NTWK SIP	0317-0010	32977
RN05	RES 3.3K NETWORK DIP	0317-0013	32977
RN06	RES 680 NTWK SIP	0317-0011	32977
RN07			
RN08	RES 680 NTWK SIP	0317-0011	32977
RN09	RES 3.3K NETWORK DIP	0317-0013	32977
RN10	RES 1.8K NTWK SIP	0317-0010	32977
RN11	RES 680 NTWK SIP	0317-0011	32977
RN12			
RN13	RES 470 OHM	0317-0014	32977
RN14	RES 470 OHM NETWORK DIP	0317-0014	32977
RN15	RES 470 OHM NETWORK DIP	0317-0014	32977
	U001	IC 74S161 DM74S161N	
2120-0080	27014		
U002			

U003	IC MC10105	2121-0057	04713
U004	IC MC10105	2121-0057	04713
U005	IC MC10102	2121-0055	04713
U006	IC MC10110	2121-0060	04713
U007			
U008	IC 74S140	2120-0059	04713
U009	IC 74LS02	2120-0012	27014
U010	IC 74S00	2120-0053	27014
U011	IC LF13202	2118-0054	27014
U012			
U013	IC LF347	2118-0095	27014
U014	IC LM311N	2119-0003	27014
U015	AMPC MOD ASSY	2130-0001H	34511
U016	IC LF356	2118-0053	27014
U017			
U018	IC 7905	2118-0071	04713
U019	IC LM317T	2118-0050T	27014
U020	IC 7824	2118-0069	04713
U021	IC 7915	2118-0092	04713
U022			
U023	IC 7924	2118-0073	04713
U024	IC 555	2118-0008	18722
U025	IC 74S161 DM74S161N	2120-0080	27014
U026	IC MC10105	2121-0057	04713
U027			
U028	IC MC10102	2121-0055	04713
U029	IC MC10105	2121-0057	04713
U030	IC MC10105	2121-0057	04713
U031	IC 74S02	2120-0082	27014
U032	IC LF347	2118-0095	27014
U033			
U034	IC 555	2118-0008	18722
U035	IC 74LS02	2120-0012	27014
U036	IC 555	2118-0008	18722
U037			
U038	IC 74S161	2120-0080	72014
U039	IC LF412CN	2118-0099	27014
U040	IC MDA-970	2103-0008	04713
U041	IC 74S04	2120-0087	27014
U042			
U043	IC 74LS02	2120-0012	27014
U044	IC LF356	2118-0053	27014
U045	IC LF356	2118-0053	27014
U046	IC CA3046	2118-0061	18722
U047			
U048	IC VM-18	2103-0005	30857
U049	IC VM-18	2103-0005	30857
U050	IC LF412CN	2118-0099	27014
U051	IC MC10102	2121-0055	04713
U052			
U053	IC MC10105	2121-0057	04713
U054	IC MC10131	2121-0062	04713
U055	IC LF356	2118-0053	27014
U056	IC CA3046	2118-0061	18722
U057			
U058	IC CA3046	2118-0061	18722
U059	IC LF356	2118-0053	27014
U060	IC LF356	2118-0053	27014

W001	.50 WIRE JUMPERS	3015-0007
W002	.50 WIRE JUMPERS	3015-0007
W003	.50 WIRE JUMPERS	3015-0007
W004	.50 WIRE JUMPERS	3015-0007
W005	.50 WIRE JUMPERS	3015-0007
W006	.50 WIRE JUMPERS	3015-0007
W007	.50 WIRE JUMPERS	3015-0007
W008	.50 WIRE JUMPERS	3015-0007
W009	.50 WIRE JUMPERS	3015-0007
W010	.50 WIRE JUMPERS	3015-0007
W011	.50 WIRE JUMPERS	3015-0007
W012	.50 WIRE JUMPERS	3015-0007
R183	.50 WIRE JUMPERS	3015-0007
R363	.50 WIRE JUMPERS	3015-0007

ITEM NO.	DESCRIPTION/QUANTITY	PART NO.	MFC
1	IC SKT 8 PIN / 12	2712-0003T	09922
2	IC SKT 14 PIN / 17	2712-0015T	09922
3	IC SKT 16 PIN / 15	2712-0018T	09922
4	IC SKT 20 PIN / 1	2712-0017	09922
5	IC SKIT 40 PIN / 8	2712-0022	09922
6	HEAT SINK / 4	4402-0010	05820
7	TRANSISTOR PAD / 4	4906-0001	13103
8	THERMAL CLIPS / 9	4402-0020	05820
9	STAND OFF 6-32 X 1.85 HEX / 4	4910-0074	
10	S/C STUDD 4-40-X 1/2 / 5	4715-0013	
11	REG BRKT / 1		34511
12	SHOULDER WASHER / 5		
13	INSULATING WASHER /5		
14	CONE WASHER / 5		
15	4-40 NUT / 5		
16	#6 FLAT WASHER / 4		
17	#6 LOCK WASHER / 4		
18	#6 X 3/8 PPH SCREW / 4		
19	CABLE TIE 4" / 5		
20	HEAT SIN / 1		34511
21	FUSE CLIP / 2	1006-0014T	75915
22	TEST POINTS	2714-0002	

TOP PRINTED CIRCUIT BOARD ASSEMBLY

REF DES	DESCRIPTION	PART NUMBER	MFC
C001	CAP CER .1 UF 50 V	0418-0008	96095
C002	CAP ELECT 6.8 UF 35V	0403-0052	74840
C003	CAP ELECT 6.8 UF 35V	0403-0052	74840
C004	CAP POLY 1 UF 100V	0410-0033	55112
C005	CAP MICA 200 PF	0415-0107	00853
C006	CAP MICA 15 PF 500V	0415-0080	00853
C007	CAP CER .1 UF 50 V	0418-0008	96095
C008	CAP ELECT 6.8 UF 35V	0403-0052	74840
C009	CAP CER .1 UF 50 V	0418-0008	96095
C010	CAP CER .1 UF 50 V	0418-0008	96095
C011	CAP POLY .1 UF 100V	0410-0011	55112
C012	CAP POLY .1 UF 100V	0410-0011	55112
C013	CAP POLY .1 UF 100V	0410-0011	55112
C014	CAP POLY .1 UF 100V	0410-0011	55112
C015	CAP POLY .1 UF 100V	0410-0011	55112
C016	CAP POLY .1 UF 100V	0410-0011	55112
C017	CAP POLY .1 UF 100V	0410-0011	55112
C018	CAP POLY .1 UF 100V	0410-0011	55112
C019	CAP POLY .1 UF 100V	0410-0011	55112
C020	CAP POLY .1 UF 100V	0410-0011	55112
C021	CAP POLY .1 UF 100V	0410-0011	55112
C022	CAP CER .01 UF 50V	0418-0014	96095
C023	CAP CER .1 UF 50V	0418-0008	96095
C024	CAP CER .1 UF 50V	0418-0008	96095
C025	CAP CER .1 UF 50V	0418-0008	96095
C026	CAP CER .01 UF 50V	0418-0014	96095
C027	CAP CER .1 UF 50V	0418-0008	96095
C028			
C029			
C030	CAP ELECT 6.8 UF 35V	0403-0052	74840
C031	CAP ELECT 6.8 UF 35V	0403-0052	74840
C032	CAP ELECT 6.8 UF 35V	0403-0052	74840
C033	CAP CER .1 UF 50V	0418-0008	96095
C034	CAP CER .1 UF 50V	0418-0008	96095
C035	CAP CER .1 UF 50V	0418-0008	96095
C036	CAP CER .1 UF 50V	0418-0008	96095
C037	CAP CER .1 UF 50V	0418-0008	96095
C038	CAP CER .1 UF 50V	0418-0008	96095
C039	CAP CER .1 UF 50V	0418-0008	96095
C040	CAP CER .1 UF 50V	0418-0008	96095
C041	CAP MICA 200 PF	0415-0107	00853
C042	CAP MICA 200 PF	0415-0107	00853
C043	CAP VAR 8-50 PF	0423-0004	90201
C044	CAP ELECT 6.8 UF 35V	0403-0052	74840
C045			
C046	CAP .001 UF 50V	0418-0016	96095
C047	CAP .001 UF 50V	0418-0016	96095
C048	CAP .001 UF 50V	0418-0016	96095
C049	CAP .001 UF 50V	0418-0016	96095
C050	CAP .001 UF 50V	0418-0016	96095
C051	CAP .001 UF 50V	0418-0016	96095
C052	CAP .001 UF 50V	0418-0016	96095
C053	CAP .001 UF 50V	0418-0016	96095
C054	CAP .001 UF 50V	0418-0016	96095
C055	CAP .001 UF 50V	0418-0016	96095
C056	CAP .001 UF 50V	0418-0016	96095

C057	CAP .001 UF 50V	0418-0016	96095
C058	CAP .001 UF 50V	0418-0016	96095
C059	CAP .001 UF 50V	0418-0016	96095
C060	CAP .001 UF 50V	0418-0016	96095
C061	CAP .001 UF 50V	0418-0016	96095
C062	CAP .001 UF 50V	0418-0016	96095
C063	CAP .001 UF 50V	0418-0016	96095
C064	CAP .001 UF 50V	0418-0016	96095
D001	DIODE 1N914	2101-0010	07263
D002	DIODE 1N914	2101-0010	07263
D003	DIODE 1N914	2101-0010	07263
D004	DIODE 1N914	2101-0010	07263
D005	DIODE 1N914	2101-0010	07263
D006	DIODE 1N914	2101-0010	07263
D007	DIODE 1N914	2101-0010	07263
D008	DIODE 1N914	2101-0010	07263
D009	DIODE 1N914	2101-0010	07263
D010	DIODE 1N914	2101-0010	07263
D011	DIODE 1N914	2101-0010	07263
F001	FUSE 1/16A	1005-0099	75915
J001	PC CONN 4 PIN	2710-0009MT	27264
J002	PC CONN 4 PIN	2710-0009MT	27264
J003	PC CONN 2 PIN	2710-0007T	27264
J004	PC CONN 2 PIN	2710-0007T	72764
J005	PC CONN 4 PIN	2710-0009MT	27264
J006	HEADER RT ANGLE 20 PIN	2710-0124	75037
J007	HEADER RT ANGLE 20 PIN	2710-0124	75037
J008	HEADER RT ANGLE 20 PIN	2710-0124	75037
J009	HEADER RT ANGLE 50 PIN	2710-0126	75037
J010	HEADER RT ANGLE 40 PIN	2710-0123	75037
J011	HEADER RT ANGLE 26 PIN	2710-0125	75037
Q001	TRANS NPN PN2484	2111-0021	27014
Q002	FET P-CH 2N5485	2114-0023	27014
Q003	TRANS PNP 2N4403	2112-0005	27014
Q004	TRANS PNP 2N4403	2112-0005	27014
Q005	TRANS PNP 2N4403	2112-0005	27014
Q006	TRANS PNP 2N4403	2112-0005	27014
Q007	TRANS PNP 2N4403	2112-0005	27014
Q008	TRANS PNP 2N4403	2112-0005	27014
Q009	TRANS PNP 2N4403	2112-0005	27014
Q010	TRANS PNP 2N4403	2112-0005	27014
Q011	TRANS NPN 2N4123	2111-0007	27014
Q012	TRANS NPN 2N4123	2111-0007	27014
R001	RES MF 10K 1% 1/8W	0307-1014	07115
R002	RES MF 10K 1% 1/8W	0307-1014	07115
R003	RES MF 4.12K 1% 1/8W	0307-1603	07115
R004	RES MF 10K 1% 1/8W	0307-1014	07115
R005	RES MF 6.04K 1% 1/8W	0307-1763	07115
R006	RES CF 1K 5% 1/4W	0300-1103	01121
R007	RES CF 2K 5% 1/4W	0300-1203	01121
R008	RES CF 4.7K 5% 1/4W	0300-1473	01121
R009	RES CF 2.2M 5% 1/4W	0300-1226	01121
R010	RES CF 10K 5% 1/4W	0300-1104	01121
R011	RES CF 470 OHM 5% 1/4W	0300-1472	01121
R012	RES CF 1K 5% 1/4W	0300-1103	01121
R013	RES CF 1K 5% 1/4W	0300-1103	01121

R014	RES CF 270K 5% 1/4W	0300-1275	01121
R015			
R016	RES CF 2K 5% 1/4W	0300-1203	01121
R017	RES MF 10K 1% 1/8W	0307-1014	07115
R018	RES MF 10K 1% 1/8W	0307-1014	07115
R019			
R020	RES CF 620 OHM 5% 1/4W	0300-1622	01121
R021	RES CF 1K 5% 1/4W	0300-1103	01121
R022	RES MF 4.02K 1% 1/8W	0307-1593	07115
R023	RES MF 1K 1% 1/8W	0307-1013	07115
R024	RES MF 16.9K 1% 1/8W	0307-1234	07115
R025	RES MF 10.5K 1% 1/8W	0307-1034	07115
R026	RES MF 11K 1% 1/8W	0307-1054	07115
R027	RES MF 15K 1% 1/8W	0307-1184	07115
R028	RES MF 17.4K 1% 1/8W	0307-1244	07115
R029	RES MF 15K 1% 1/8W	0307-1184	07115
R030	RES VAR 1/2W 10% 5K	0326-0009	01121
R031	RES VAR 1/2W 10% 2K	0326-0008	01121
R032	RES MF 3.01 K 1% 1/8W	0307-1473	07115
R033			
R034	RES MF 6.49K 1% 1/8W	0307-1793	07115
R035	RES MF 1K 1% 1/8W	0307-1013	07115
R036	RES MF 7.68K 1% 1/8W	0307-1863	07115
R037	RES MF 20K 1% 1/8W	0307-1304	07115
R038	RES MF 100K 1% 1/8W	0307-1015	07115
R039	RES MF 2K 1% 1/8W	0307-1303	07115
R040	RES MF 499 OHM 1% 1/8W	0307-1682	07115
R041	RES MF 249 OHM 1% 1/8W	0307-1392	07115
R042	RES MF 49.9 OHM 1% 1/8W	0307-1681	07115
R043	RES VAR 1/2W 10% 1K	0326-0007	01121
R044	RES CF 6.8K 5% 1/4W	0300-1683	01121
R045	RES CF 6.8K 5% 1/4W	0300-1683	01121
R046			
R047			
R048	RES CF 560K 5% 1/4W	0300-1565	01121
R049	RES CF 75 OHM 5% 1/2W	0301-1751	01121
R050	RES CF 75 OHM 5% 1/2W	0301-1751	01121
R051	RES CF 75 OHM 5% 1/2W	0301-1751	01121
R052	RES CF 75 OHM 5% 1/2W	0301-1751	01121
R053	RES CF 75 OHM 5% 1/2W	0301-1751	01121
R054	RES CF 75 OHM 5% 1/2W	0301-1751	01121
R055	RES CF 75 OHM 5% 1/2W	0301-1751	01121
R056	RES CF 75 OHM 5% 1/2W	0301-1751	01121
R057	RES CF 2K 5% 1/4W	0300-1203	01121
R058	RES CF 2K 5% 1/4W	0300-1203	01121
R059	RES CF 100K 5% 1/4W	0300-1105T	01121
R060	RES CF 150K 5% 1/4W	0300-1155	01121
R061	RES CF 3K 5% 1/4	0300-1303	01121
R062	RES CF 3K 5% 1/4	0300-1303	01121
R063	RES CF 3K 5% 1/4	0300-1303	01121
R064	RES CF 3K 5% 1/4	0300-1303	01121
R065	RES CF 3K 5% 1/4	0300-1303	01121
RN01	RES NTWK 10K X9 SIP	0317-0006	32977
RN02	RES NTWK 10K X9 SIP	0317-0006	32977
RN03	RES NTWK 1K X 8 DIP	0317-0012	32977
S001	SWITCH DIP 4 POS	2515-0007	71450
TP01	TEST POINT TER	2714-0002	18310
TP02	TEST POINT TER	2714-0002	18310

TP03	TEST POINT TER	2714-0002	18310
TP04	TEST POINT TER	2714-0002	18310
U001	IC LF347	2118-0095	27014
U002	IC LF347	2118-0095	27014
U003	IC LF347	2118-0095	27014
U004	IC LF347	2118-0095	27014
U005	IC LF13202	2118-0054	27014
U006	IC 4051	2120-0078	04713
U007	IC 4051	2120-0078	04713
U008	IC LM311N	2119-0003	27014
U009	IC LM399H	2118-0030	27014
U010	IC LF347	2118-0095	27014
U011	IC LF13202	2118-0054	27014
U012	IC LF347	2118-0095	27014
U013	IC DAC312	2122-0040	06665
U014	IC DAC312	2122-0040	06665
U015	IC 74LS151	2120-0077	12944
U016	IC 74LS00	2120-0017	12944
U017	IC 74LS93	2120-0021	12944
U018	IC 74LS374	2120-0083	12944
U019	IC 74LS374	2120-0083	12944
U020	IC 74LS374	2120-0083	12944
U021	IC 74LS374	2120-0083	12944
U022	IC 74LS374	2120-0083	12944
U023	IC 6520	2122-0015	34576
U024	IC 6520	2122-0015	34576
U025	IC 6522	2122-0030	34576
U026	IC 6522	2122-0030	34576
U027	IC 6522	2122-0030	34576
U028			
U029			
U030	IC 2813A	2122-0031	56289
U031	IC 2813A	2122-0031	56289
U032	IC 4514	2121-0039	07263
U033	IC 74LS138	2120-0084	12944
U034	IC 74LS138	2120-0084	12944
U035	IC 7416	2120-0081	12944
U036	IC 7416	2120-0081	12944
U037	IC 8279	2122-0032	34649
U038	IC 75160	2120-0085	01295
U039	IC 75161	2120-0086	01295
U040	IC 9914	2122-0033	01295
U041	EPROM 628	2122-0042H	34511
U042	EPROM 628	2122-0035	34511
U043	EPROM 628	2122-0036	34511
U044	EPROM 628	2122-0041	34511
U045	IC 52B13	2122-0029	61394
U046	IC 74SL138	2120-0084	12944
U047	IC 74LS139	2120-0024	27014
U048	IC 2114 RAM	2122-0026	01295
U049	IC 2114 RAM	2122-0026	01295
U050	IC 2114 RAM	2122-0026	01295
U051	IC 2114 RAM	2122-0026	01295
U052			
U053			
U054	IC 74LS30	2120-0036	27014
U055	IC 74LS00	2120-0053	12944
U056	IC 74LS04	2120-0019	27014
U057	IC 74LS04	2120-0019	27014
U058	IC 74LS20	2120-0028	27014
U059	IC 74LS04	2120-0019	27014

U060	IC 6502	2122-0034	34576
U061	IC 555	2118-0008	18722
U062	IC 555	2118-0008	18722
U063			
Y001	CRYSTAL 1 MHZ	1220-0009	75378

ITEM NO.	DESCRIPTION/QUANTITY	PART NUMBER	MFC
I001	IC SKT 8 PIN / 3	2712-0003T	09922
I002	IC SKT 14 PIN / 16	2712-0015T	09922
I003	IC SKT 16 PIN / 9	2712-0018T	09922
I004	IC SKT 18 PIN / 6	2712-0024	09922
I005	IC SKT 20 PIN / 9	2712-0017	09922
I006	IC SKT 24 PIN / 2	2712-0016	09922
I007	IC SKT 28 PIN / 4	2712-0023	09922
I008	IC SKT 40 PIN / 8	2712-0022	09922
I009	POLARIZING KEY 3M HEADER / 6		75037
I010	STAND OFF 6/32 X.5 / 4	4910-0070	99256

DAMAGE & SHORTAGE

Before you fully unpack any unit READ THIS for your protection

(THIS INFORMATION APPLIES ONLY ON SHIPMENTS WITHIN THE UNITED STATES)

DAMAGE This shipment was packaged and delivered to the carrier with the utmost care to insure safe delivery of goods. When shipment is received and signed for by the transportation company, consignor's responsibility ceases. Do not accept shipment which evidences damage or shortage until agent of carrier endorses a statement of the irregularity on the face of the transportation receipt. Without documentary evidence, claim cannot be filed.

CONCEALED DAMAGE Interstate Commerce Commission has indicated that a carrier is as much responsible for concealed damage as for visible damage in transit. Upon receipt of shipment, promptly unpack and check thoroughly. If concealed damage is discovered, cease further unpacking and request immediate inspection by local agent of carrier. A written report of the agent's findings, with his signature, is necessary to support claim.

SHORTAGE Check shipment against shipping papers. Do not discard packing materials or packing cases until contents have been found to be correct. The removal of badly needed items, before shipment has been checked, may create a shortage. Check all possibilities before reporting a shortage.

CLAIMS If your agent or carrier has been given an opportunity to inspect the shipment, any claim for a shortage or damaged merchandise can be handled as a simple and routine procedure. Claims must be filed by consignee. Shipping terms are f.o.b. Carson City, Nevada.

LOSS In the event of complete loss, claim will be handled in the same manner as for Shipping Damage or Shortage.

**Note further information below.*

SHIPPING DAMAGE OR SHORTAGE

AIR FREIGHT – Claim must be initiated at point of destination. Claim must be filed by submitting a letter on company stationery with an explanation of the extent of damage or loss and forwarded with a copy of the original* air bill, and original invoice or photostat of same, to the airline having carried the shipment.

*Upon request certified photostatic copies of original papers held by Dynatech-Nevada required in support of port of claims will be made available.

PARCEL POST / UPS

PLACING CLAIM FOR DAMAGE – For those shipments insured by Parcel Post, the addressee initiates the claim by filling out Post Office Dept. Form 3812, "Request for Payment of Domestic Postal Insurance". Item 12 is to be other than Dynatech-Nevada. Damaged material must be returned to the Post Office of address for inspection. A new purchase order is required by Dynatech-Nevada to cover the cost of repairs (or in the case of loss or refiling-replacement order). Damaged material will be repaired and returned. Party named in item 12 of form 3812 will receive reimbursement for repair cost from Post Office Department.

PLACING CLAIM FOR LOSS – In the event of a report to consignor of loss or refiling, Post Office Dept. Form 3812 will be initiated by Dynatech-Nevada at point of origin. If, after Post Office investigation, the material is not located, disposition from this point will be the same as stated in the above paragraph—"Placing claim for damage."

PLACING CLAIM FOR DAMAGE TO SHIPMENTS BY UNITED PARCEL—The addressee must notify Dynatech-Nevada, who will notify United Parcel Service giving the shipper's number and date parcel was shipped. United Parcel Service will send a representative to inspect the damage and advise proper disposition. A new purchase order is required by Dynatech-Nevada to cover the cost of repairs or in the case of loss or refiling, a replacement order. Damaged material will be repaired and returned.

DYNATECH NEVADA
INCORPORATED
Formerly NEURODYNE-DEMPSEY

2000 ARROWHEAD DRIVE, P.O. BOX 1925, CARSON CITY, NEVADA 89701 (702) 883-3400

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PROPERTY OF
ELEC/MICROWAVE DEPT
BLDG. 802 RM. 540